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Content

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GEOGRAPHIC INFORMATION SYSTEMS (GIS) METHODS FOR LANDSCAPE RESEARCH AT PĂULENI-CIUC "*DAMBUL CETĂŢII*" (JUD. HARGHITA)

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Abstract: *The prehistoric settlement at Păuleni-Ciuc "Dâmbul Cetatii" is positioned in a unique location, from the perspective of both local and regional scales. The following paragraphs will draw upon Geographic Information Systems (GIS) analyses to document some aspects of the settlement's location.A geographic information system (GIS) is a potent suite of tools used for the construction, curation, and analysis of spatial data. Although GIS is frequently associated with computer mapping, applications extend further than this to incorporate the logics of representing complex real-world phenomena in a digital environment. Therefore, for archaeologists a GIS is best envisioned as a toolkit for examining questions of space. We use GIS methods to analyze the visualscape of the Păuleni-Ciuc landscape. Visualscape refers to the "the spatial representation of any visual property generated by, or associated with, a spatial configuration". Two characteristics of the visualscape provide insight to Păuleni-Ciuc"s location: visual dominance and visual prominence.*

Keywords: *Eneolithic, Cucuteni-Ariușd Culture, Transylvania, Settlement, georeferenced data*

Rezumat: *Așezarea preistorică de la Păuleni-Ciuc "Dâmbul Cetății" este poziționată într-o locație unică, din perspectiva ambelor scări, cea locală și cea regională. Sistemul de georeferenţiere este unul care cuprinde o serie de unelte folosite la crearea, depozitarea şi reprezentarea unor date spaţiale necesare documentării unor aspecte ale amplasării sitului preistoric. Utilizarea Sistemelor de Informații Geografice (GIS) ca metodă de analiză a vizibilității și peisajului de la Păuleni-Ciuc, se referă la "reprezentarea spațială a oricărei* *proprietăți vizuale generate sau asociate cu o configurație spațială". Două caracteristici ale vizibilității sitului furnizează informații pentru analiza vizibilității aşezării de la Păuleni-Ciuc: poziția dominantă vizuală și importanța vizuală. Pentru a examina aceste caracteristici ale zonei din jurul sitului Păuleni-Ciuc, ne-am construit un model de date precise, combinate cu datele existente și s-au efectuat analize de vizibilitate ale zonei.*

Cuvinte cheie: *Eneolitic, Cucuteni-Ariușd, Transilvania, așezare, georeferențiere*

Introduction

The site at Păuleni-Ciuc, also known as (Șoimeni/Ciomortan) ”*Dambul Cetăţii”*, lies in a saddle between three hill peaks in the foothills above the Ciuc Depression. The settlement was repeatedly inhabited during the Eneolithic, Early Bronze Age, and Middle Bronze Age by populations belonging to the Ariuşd-Cucuteni, Costişa-Ciomortan, and Wietenberg cultures (Székély 1970, 71-76; Cavruc 2000, 99; Cavruc, Dumitroaia 2000, 131-154; Cavruc, Rotea 2000, 155-172; Cavruc, Buzea 2002, 41-88; Lazarovici *et al*. 2000, 103-30; Lazarovici *et al.* 2002, 19-40; Buzea, Lazarovici, 2005, 25-88; Buzea 2009; Lazarovici, Buzea 2009, 130-131; Buzea, Briewig 2010, 205-246; Ștefan *et al.* 2010, 427-436; Whitlow, 2010, 413-426; Beldiman *et al*. 2012; Whitlow *et al.* 2013).

This paper examines the landscape corresponding to the Eneolithic component of the site. The site's location varies from other Ariuşd-Cucuteni settlements in intriguing ways; it is the highest of the recorded Eneolithic settlements at approximately 850 m, and rather than settling on a visually prominent point the population chose to inhabit a small depression between two peaks and a ridgeline. It is also close to the Ghimeş-Faget pass, one of the corridors through the Eastern Carpathian Mountains.

In an attempt to understand the significance of the site‟s location we apply landscape archaeology methods to the site. Landscape archaeology shifts research focus from the site to the relation between past people and their ecological and social environment (David, Thomas 2008, 38). Landscape research assumes people were active, mobile agents, and the activities that were significant to social practices occurred not only on site but at numerous points in the broader landscape. Here, we apply one aspect of landscape archaeology – *visibility analysis* – to examine the position of Păuleni-Ciuc in the Carpathian landscape.

Perception is a crucial component of human engagement with the world. Although exceptions do exist, for most people vision is the primary sense through which they observe the world around them. Teaching individuals to notice (perceive) certain aspects of the landscape - such as vegetation patterns, unique topographic features, or natural springs – is a major component in enculturation (Ingold 2000, 168). While it is impossible to accurately and totally model past perception, archaeologists may approach the importance of vision by examining the cognitive processes through which a person perceives the visual structure of the landscape (Gibson, 1979).

We use geographic information systems (GIS) methods to analyze the visualscape of the Păuleni-Ciuc landscape. Visualscape refers to the “the spatial representation of any visual property generated by, or associated with, a spatial configuration" (Lobera 2003, 30). Two characteristics of the visualscape provide insight to Păuleni-Ciuc‟s location: visual dominance and visual prominence. To examine these features we constructed a precise model of the area around Păuleni-Ciuc, combined it with existing data, and performed viewshed analyses of the area.

Creation of the Elevation Model

Landscape analysis begins with the acquisition or construction of accurate and precise topographic data. Freely available data exists for Harghita County in the form of the Shuttle Radar Topography Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) digital elevation models (DEM). SRTM DEMs have a resolution of 90 m² and ASTER Global DEMs of 30 m². Some researchers have noted that numerous errors in the ASTER GDEM data that are not found in SRTM data, however a recent comparison of ASTER GDEM data with ground control points indicates the vertical accuracy of ASTER GDEM data is 20 m at 95 % confidence (ASTER GDEM 2009; http://asterweb.jpl.nasa.gov/gdem.asp).

We compared the elevation of ASTER GDEMs to GPS readings recorded at site and found a vertical error of 10 m. The ASTER GDEMs were subsequently adjusted; however the relatively limited area of the GPS survey means significant error may be present in other portions of the data.

Viewshed analysis is affected by the precision of the topographic data, especially close to viewpoints where modest changes may completely block line of sight. DEMs with a 4 m resolution are ideal (Riggs, Dean 2007, 193), although difficult to acquire. In light of this requirement and the need to construct a higher resolution 3D model of the Păuleni-Ciuc site, the author conducted a topographic survey of the area immediately surrounding the settlement as part of the 2010 research project. The surveyed area covered. 65 Km² including the site, the three encircling hills, and the southern slope (Figure 1). Data were collected with a Garmin GPSmap 60Csx unit. Field testing of the Garmin GPSmap series verified the 3 m accuracy of the unit in clear conditions (Wing, Eklund 2007, 92).

Measurements were continuously collected every ten meters with additional 60-90 second measurements taken of prominent topographic features. Since spatial interpolators and triangular irregular networks were used to create the elevation and three dimensional models a regular survey grid was not necessary. A non-gridded survey approach, in which the density of measurements corresponds to the degree of variation in topography, will accurately reflect the landscape (Fletcher, Spicer 1988) while saving field and processing time.

The coordinate point data from the GPS was interpolated to create a continuous surface. Interpolation is used to convert the discrete measurements from the GPS survey into a continuous field of data by estimating values at unknown locations based on nearby measured values (Hageman, Bennett 2000, 115).

Interpolating the GPS data creates a regularly spaced grid of elevation values, referred to as a Digital Elevation Model (DEM).

Interpolation methods are classified based on a number of attributes: whether the operations are local or global, constrained or unconstrained, and exact or approximate (Wheatley, Gillings 2002, 184). Local operations draw only on nearby known values to estimate the unknown value, while global operations use all known values. Therefore, a global operation is more likely to produce a smooth surface but is susceptible to aberrations caused by unusually high values, while unusually high values will create only localized steps or peaks in a local operation. An interpolator is constrained if the estimated value cannot be higher or lower than the known values used to calculate it and unconstrained if the estimated value can exceed the range of known values. Finally, an interpolator is exact if the resulting surface passes through all known values, and approximate if the resulting surface does not pass through all known points.

Numerous methods of spatial interpolation were developed to emphasize different combinations of these parameters. Two methods for the survey model are examined here: inverse distance weighting (IDW) and natural neighbor (NN). IDW is a local, exact, and unconstrained interpolator which heavily weights the closest values when calculating an unknown value. IDW is also a trend model: it is based on the assumption that the pattern of the analyzed data fits a mathematical trend. Trend models are similar to regression analysis in three dimensions and most effective when the underlying patterns are relatively simple (Wheatley, Gillings 2002, 187- 189). However, the hilly topography around Păuleni-Ciuc cannot be described by a simple model. The surfaces created by the IDW interpolator for Păuleni-Ciuc created a series of false peaks and steps in areas where the elevation changed suddenly, such as on the southern slope of the site (Figure 2). The natural neighbor interpolator is a local, constrained, and exact operation which uses Voronoi diagram to calculate a surface (Sibson 1981, p. XX).

A Voronoi diagram divides a plane into polygons so that every point within each polygon is closest to the generating point. In a NN operation Voronoi polygons are calculated for all known values, and then a second set of Voronoi polygons are calculated for the unknown values. Weights are assigned to the known values using the overlap between the first and second set of Voronoi diagram, and the weighted known values are in turned used to calculate each unknown value. Unlike IDW, the NN interpolator did not produce the same artificial steps (Figure 3).

Using the natural neighbor interpolator we created DEM of the 65 Km^2 survey area with a cell resolution of 5 Km^2. The DEM was then converted into a triangulated irregular network (TIN) for 3D display. A TIN is a vector model: the landscape is represented by a series of nodes (points) with elevation values and triangular faces drawn between these nodes. The faces are created by selecting a set of points according to Delaunay triangulation, "… in which the resulting triangles are closest to equilateral, and in which the circles whose circumferences pass through the points of the triangles contain no other points" (Wheatley, Gillings 2002, 149).

Unlike DEMs, in which values are recorded at regular intervals on a grid, a TIN may be generalized to remove unnecessary measurements (e.g., regularly spaced elevation measurements on a flat surface). Since the TIN is a generalized vector model it can be rendered faster in a 3D environment than a DEM.

The survey area TIN was incorporated into a larger TIN generated from ASTER GDEM data, allowing us to situate the site in the broader landscape of the Eastern Carpathians (Figure 4). This TIN model is used for 3D representations of the site. It is possible to „drape" imagery (e.g., satellite imagery, orthophotos or other rasters) over the TIN frame to project that data in 3D. The survey DEM was also combined with a DEM of the Ciuc Depression and Eastern Carpathian Mountains. This DEM is used for modeling visibility at Păuleni-Ciuc.

Modeling Visibility

The DEMs created through the topographic survey were used in a visibility analysis of Păuleni-Ciuc and the Eastern Carpathian landscape. Within GIS visibility is based on the concept of Line of Site (LoS): a line is drawn between the viewpoint and the target point (Figure 5). If the line does not intersect with any intermediate cells the target point is regarded as visible. If the line intersects a cell that cell „blocks" the LoS and the target cell is not visible. The viewpoint may be modified by a vertical offset to represent the height of the observer. The closer a viewpoint to the ground, the more likely the LoS will be blocked by slight changes in topography. Therefore it is crucial to include a vertical offset to reflect the viewing individual"s height.

Here the LoS is modeled on a „bare earth" surface without vegetation. Vegetation plays a crucial role in visibility however modeling vegetation in a viewshed is complex. Vegetation may be modeled by raising elevation values to account for canopy height - this approach assumes that vegetation is impenetrable to sight. Alternatively, vegetation may be modeled as a separate layer above the DEM with a „permeability" factor: for each vegetation cell the LoS passes through visibility decreases either linearly or exponentially (Dean 1997; Llobera 2007). The visibility of each cell is shifted from a binary measurement (visible/not visible) to a percentage value representing the likelihood the cell is visible through vegetation.

While this method allows the effects of vegetation to be included it requires the input of a paleo-vegetation model. Since modeling the paleoenvironment of Păuleni-Ciuc or the Eastern Carpathian Mountains is beyond the scope of this paper we use only the DEM as an input in our model.

A second modification to LoS is visible exposure (Llobera 2005). The basic LoS function only measures whether an uninterrupted LoS may be drawn between two points. It does not consider the degree of visibility of features in the observable cell. The visibility of these features is based on two additional factors: distance from the viewpoint (farther objects are harder to see) and the slope of the land relative to the angle of LoS. Distance exposure is calculated by factoring in the normalized horizontal distance between viewpoint and observable point. Visible exposure is modeled by calculating the orthonormal vector (an angle perpendicular to the ground slope with a single unit length) (ibidem, 184-185).

The exposure is the determined by an additional vector intersecting the orthonormal and LoS vectors (Figure 6). Angular exposure may be calculated for each cell using the ground slope, LoS angle, distance and vertical and horizontal distance between the viewpoint and observable point.

Visible exposure represents visibility not as a binary measurement (visible/not visible) but as a percentage representing how visible each cell is. Nearby cells with a close to perpendicular angle between ground slope and LoS are very visible, and more distance cells with a close to parallel angle have a very low visible exposure. Although visible exposure is a more rigorous method of visibility than LoS, the additional calculations require the creation of additional rasters and have relatively large processing needs. This extra computing time means visible exposure models may not be feasible for large datasets. Here visible exposure is limited only to measurements of visibility at Păuleni-Ciuc – the cumulative viewshed analysis of visibility in the Ghimeş-Faget pass required too many calculations for visible exposure to be feasibly implemented.

A single LoS provides relatively little information about viewing the landscape. However, multiple LoS may be aggregated to produce a „viewshed‟: the total area visible from any given viewpoint. Within ArcGIS the viewshed functions calculates LoS between a single viewpoint and every cell within a given radius. As with LoS, viewsheds may be modified to account for the height of the viewer. Other parameters include direction (full 360º viewshed or a smaller angle representing the orientation of the viewing agent). Figure 7 displays the viewshed (simple LoS and visible exposure) for Păuleni-Ciuc.

A single viewshed may be aggregated into larger models through cumulative viewshed analysis (CVA) (Wheatley 1995). CVA calculates viewsheds for multiple viewpoints resulting in models of visual prominence and dominance. Archaeologists have used CVA to measure the visual structure of the landscape by calculating the visibility of each cell (Gillings 2009). CVA may produce two types of outputs. A visual dominance model measures the total area visible from each cell in the landscape. This model is useful for determining the areas with the greatest visibility and the areas with the least visibility. Some functional sites (e.g., watchtowers, forts) are more likely to be located in areas with a commanding view of the landscape – this may be represented through visual dominance.

The second model is visual prominence – how visible a given cell is in the landscape. Unlike dominance, a visual prominence model identities the features most, and least, likely to be seen from multiple points in the landscape. This model is useful for identifying highly visible topographic features which may be used in way finding, or hidden areas within the landscape.

The Visual Landscape at Păuleni-Ciuc

For this project we designed four visual models for Păuleni-Ciuc and the Eastern Carpathian landscape: a visual dominance model, visual prominence model, and two cumulative viewsheds for pathways through the Carpathian Mountains. These models were designed with ArcGIS 9.3 using the spatial analyst and 3D analyst extensions.

The visual dominance and visual prominence models were made to investigate the location of the site with regards to the visual structure of the landscape. Both models cover a 91.75 km² area including Păuleni-Ciuc, Şumuleu, the Ciuc Depression and the western foothills of the Ciuc range. Both models use a 30 m² ASTER GDEM for the elevation values and viewpoints placed on a 100 m grid. In order to avoid edge effects (Lake et al. 1998, 37), (viewpoints on edges returning lower values because they „see" off the map) the ASTER GDEM extended beyond the study area boundaries by 16 km in each direction. For viewpoint parameters we assume an individual 1.6 m tall looking in all directions (i.e., 360º horizontal and 180º vertical) and an absolute visible extent of 16km with the curvature of the earth factored in.

For the visual dominance model a viewshed was calculated for each viewpoint. The number of visible cells in each viewpoint was calculated and converted back to the raster cell value for that viewpoint (Figure 8). The result is a raster which displays the total number of visible cells for each viewpoint. The prominence model summed the viewshed results for each cell (Figure 9). This creates a raster which displays the number of times each cell can be seen from all other cells.

The major viewpoints within the landscape are located on Mt. Şumuleu and on a high ridgeline to the northeast of Păuleni-Ciuc. The settlement itself is located in an area of extremely low visibility due to the hills located to the north, east, and west. Visibility from the site is limited to the valley and hills immediately to the south and to a small area of the Ciuc Depression and Harghita range. The northeastern face of Şumuleu is also visible however the mountain blocks the site"s view of the southern Ciuc Depression. Păuleni-Ciuc"s low visibility may be overstated, however: areas of high visibility may be found just to the north and west of the site.

While the location of the actual settlement does not command an extensive view, it is located near to areas that still would have allowed its occupants to survey the landscape. Visual dominance was not a high priority, but visual prominence may have been. While the settlement is within a kilometer of four highly visible promontories or ridgelines, it is located in an area with a very low visual prominence. The settlement is effectively hidden within the foothills and would not have been visible from the Ciuc Depression.

To further investigate visibility at Păuleni-Ciuc, we now consider how the site was viewed by those approaching it from the east, across the Carpathians. To do this we model movement from the Cucuteni site at Poduri-Dealul Ghindaru across the Carpathian Mountains via the Ghimeş-Faget pass. To model movement through the Carpathians we used a set of tools collectively referred to cost-distance and cost-surface models. ArcGIS contains functions which calculate the optimal path across a landscape based on the cost of moving through each cell. Cell cost is determined by a cost-surface raster, which represents the cost of moving through a cell. Cell costs may be based on slope and terrain type, or on subjective factors such as the visibility of the path (Lee, Stucky 1998, 892) or the proximity to settlements and other cultural factors (Llobera 2000, 71).

We use two factors: surface distance and slope. Slope was calculating using the slope function in ArcGIS spatial analyst. The surface distance was calculated for each cell by calculating the length of a hypotenuse using slope degree and cell size. This method determines the total distance an agent must move across a cell based on the inclination of the land – steeper cells have a larger surface distance because agents must climb a vertical distance as well as traverse a horizontal distance. The slope value was then recalculated to reflect the increased cost of climbing steeper angles. A cutoff value of 35° was selected; agents would not attempt to move across any cells with a steeper slope. Surface distance and slope cost were combined to produce two models. In the first distance and slope were equally weighted, producing a model which minimizes slope costs. Cells with little to no change in slope had cost values lower than the actual surface distance of the cell. The second model used a minimum slope cost of one, assuring that the minimum cost of traversing each cell was at least the surface distance cost. The second model was much less attuned to slope change and favored shorter distances of travel instead.

It must be emphasized that these models do not conform to actual paths. Cost-path models assume the optimum path is based on a series of local decisions (e.g., which of the immediate cells is easiest to travel to?) while studies of path finding indicate people are much more likely to choose paths based on global decisions (e.g., is the path close to desirable locations?) or paths within sight of known landmarks (Golledge 2003).

The strength of the cost-distance models lies in the ability to predict a path based on certain parameters, and to compare variations in paths based on shifting these parameters. The two paths show a great degree of difference (Figure 10). The path minimizing slope change tracks very close to the Ghimeş pass, while the path minimizing distance instead shifts south to follow an E-W ridgeline. Path 2 (51 km) is only half the horizontal distance of Path 1 (106.5 km), however the total vertical ascent is significant greater.

To model visibility traveling to Păuleni-Ciuc, viewpoints were created at one kilometer intervals on both paths. Viewsheds were generated for each viewpoint, and the results added together to create cumulative viewsheds for both paths (Figure 11, 12). These cumulative viewsheds represent prominence viewgrids for the areas seen by both paths; higher values indicate areas seen from more location on the paths. The path CVAs were also projected in 3d (Figure 13, 14). The CVA for each path was used to clip the ASTER GDEM, creating a raster which displayed only elevations of visible points. These rasters were converted to TINs and projected over a flat DEM. The resulting model represents the visible landscape in 3D, and the non-visible landscape in 2D. These models make it possible to examine the visual features at multiple points in the journey across the Carpathians.

People use a set of pathfinding behaviors when they navigate a landscape, including: homing behavior and piloting (ibidem, 28-29). Homing behavior involves constantly positioning oneself relative to a point of origin, and is useful when the destination is not well known. In contrast, piloting behavior is used when a sequence of landmarks leading to a destination is known and the individual can always locate themselves relative to the nearest landmark. The visual structure of the Carpathian landscapes likely restricted travelers to piloting behavior, following prominent ridgelines or peaks through the Carpathian passes. Using the prominence viewgrids it is possible to identify which features may have represented homing features, allowing us to reconstruct hypothetical models of wayfinding through the mountains. It is interesting to note that while the first stages of both path follow defined features, each path contains a segment where travelers must navigate with relatively low visibility. This occurs in Path1 where they must veer west to exit the Ghimeş-Faget pass, and in Path2 where they must cross a stream valley before ascending the ridgeline to the east of Păuleni-Ciuc.

In both cases Păuleni-Ciuc is hidden from the path viewsheds until the final approach (1 km from the site on Path1, 1.5 km from the site on Path2). Travelers would have to use other highly visible features to locate the site. These would most likely be Şumuleu from Path2, and a combination of Şumuleu and the hills projecting into the Ciuc Depression from Path1.

Neither path crosses the viewshed from the site; Path2 approaches the site from “behind”, outside even the viewsheds of the higher visibility points.

Conclusions

The path CVAs reinforce the inferences made from the prominence viewgrid: Păuleni-Ciuc is situated in such a way as to be hidden in the landscape. Anyone wishing to travel to the settlement would require knowledge not only of the Carpathian Mountains, but also of the specific location of the settlement relative to other features. This analysis suggests local knowledge was of paramount importance. Unable to see the settlement, travelers would have to be capable of associated local topographic features with the occupation. For those living at the settlement such recognition was likely gained through activities around the settlement. We may also hypothesize that other nearby people may have traveled to or close to the settlement to complete certain tasks. Finally, while the settlement may be easily visible that does not suggest its inhabitants lacked information; as the visual dominance model has shown they were near a number of locations with a commanding view of the depression.

The above methods, and resulting conclusions, are intended only as a pilot study of the potential landscape archaeology and geographic information systems offer to archaeological research. Future research can improve on the visibility models by better incorporating vegetation or visual exposure. Additionally, alternative paths through the Carpathian Mountains should be considered both in terms of the travel cost and visibility along the paths. Finally, the examination of the visual structure of the landscape around Păuleni-Ciuc should be compared to that of other settlements to determine possible functional or strategic variations in settlement location.

Figures

Figure 1. Survey Area

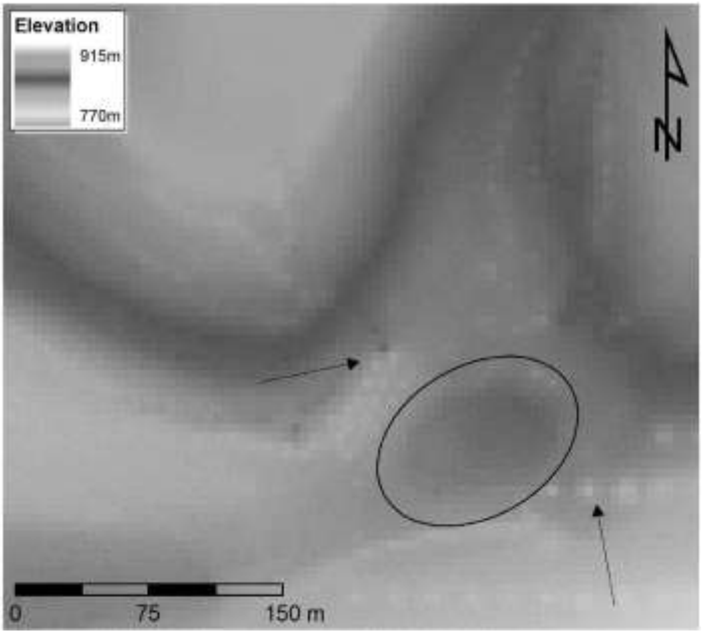

Figure 2. IDW Example

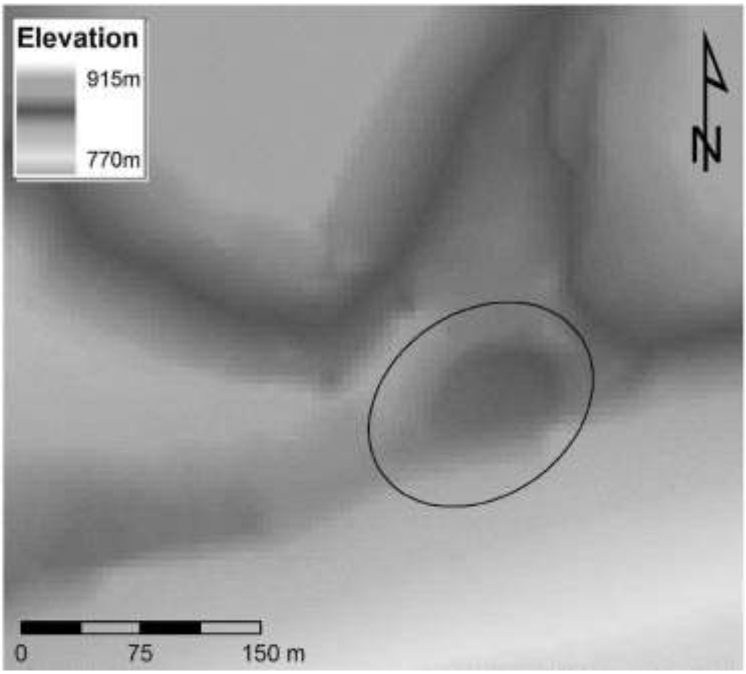

Figure 3. NN example

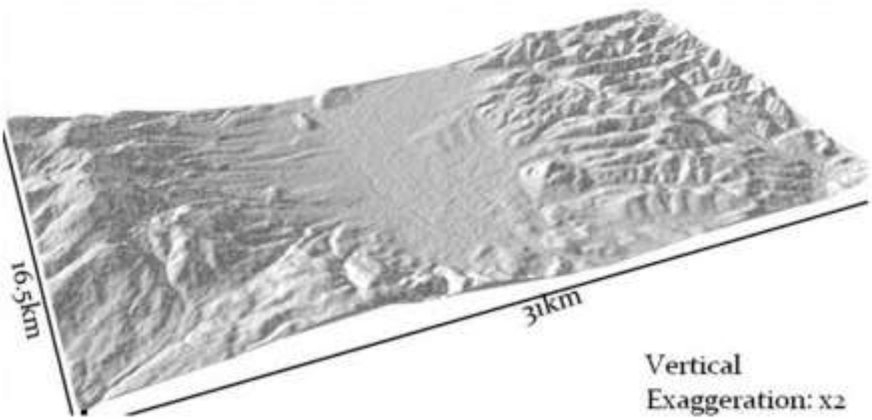

Figure 4. TIN Ciuc Depression

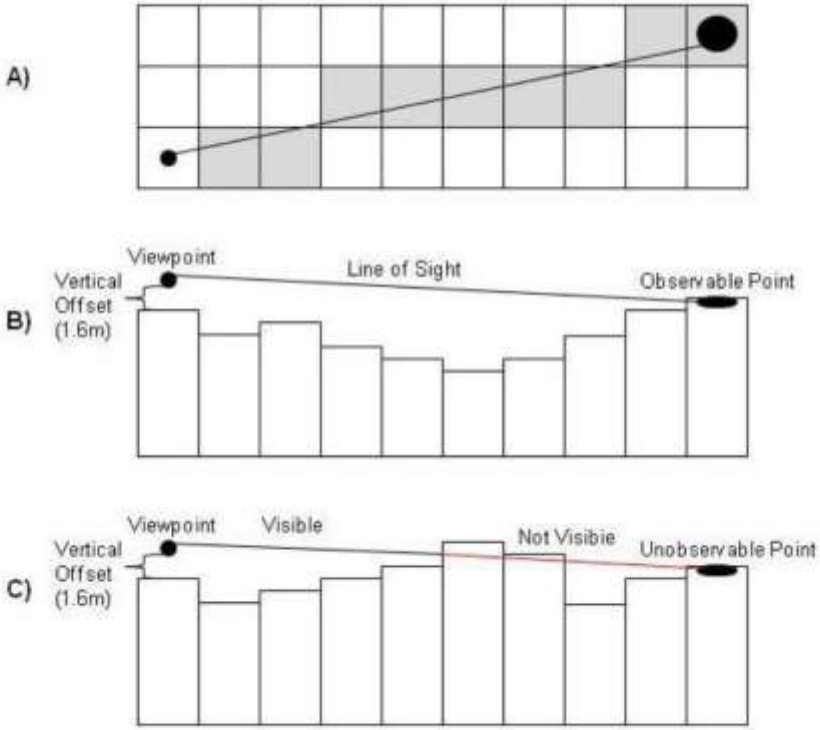

Figure 5. LoS

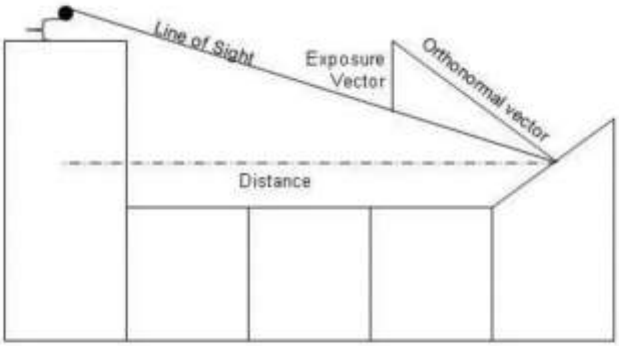

Figure 6. Visual Exposure

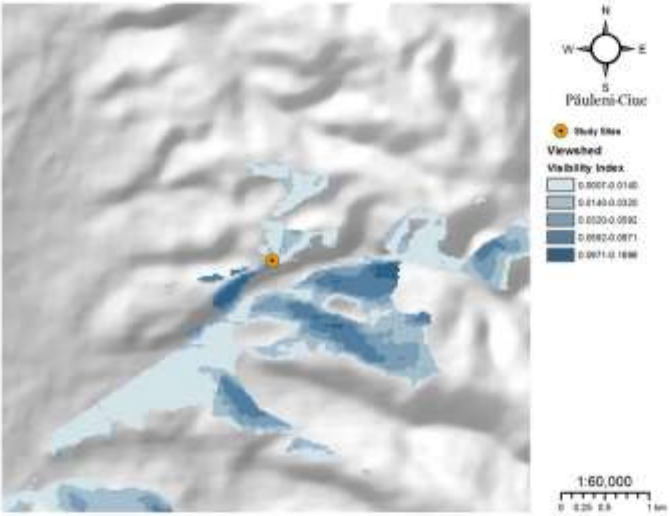

Figure 7. Păuleni Viewshed

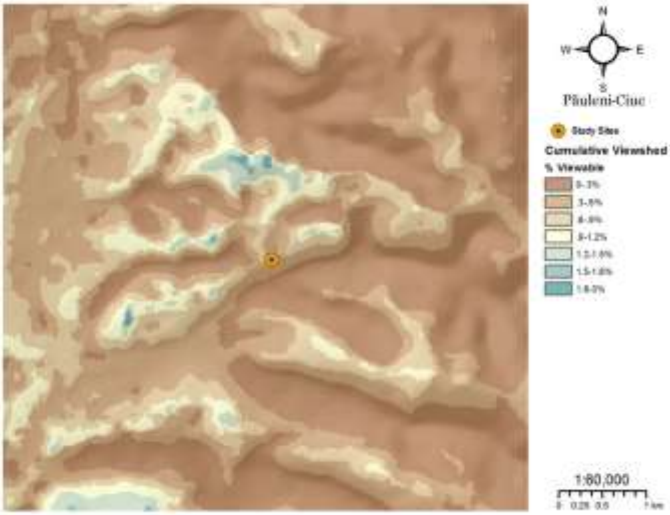

Figure 8. Visual Dominance

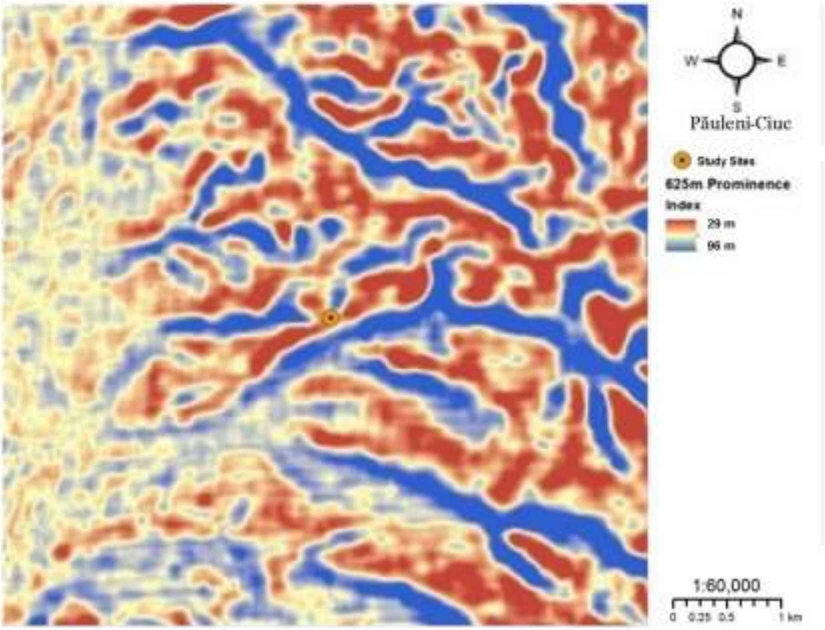

Figure 9. Visual Prominence

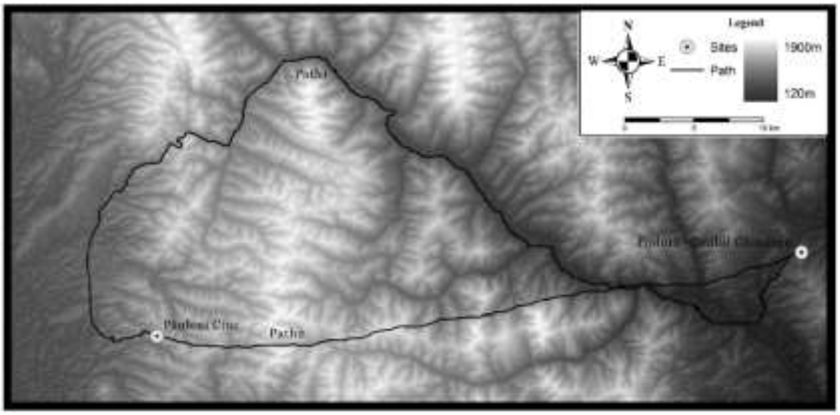

Figure 10. Cost Paths

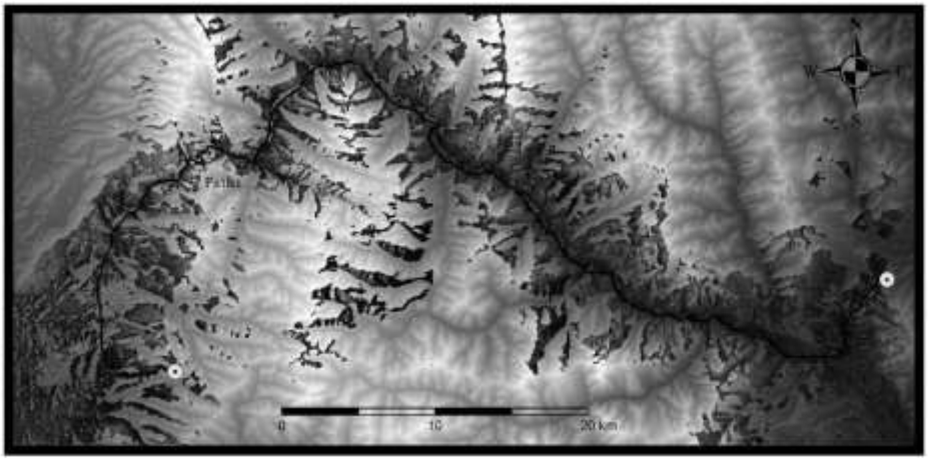

Figure 11. Path 1 CVA

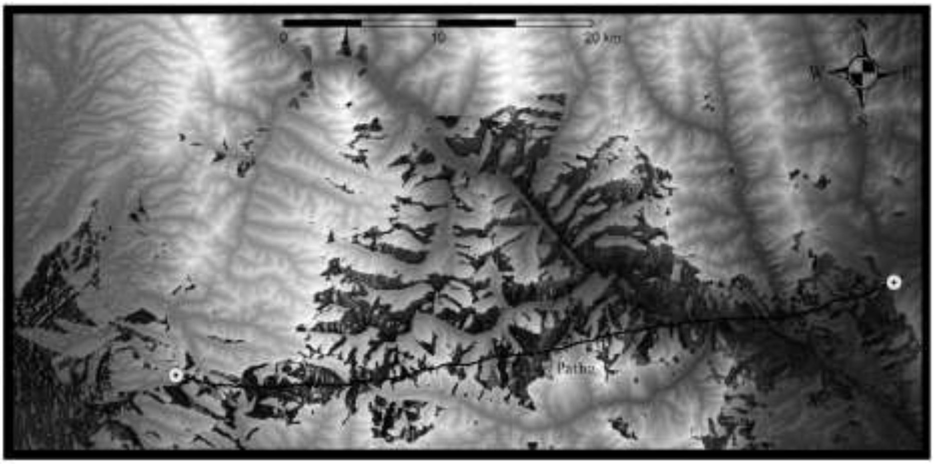

Figure 12. Path 2 CVA

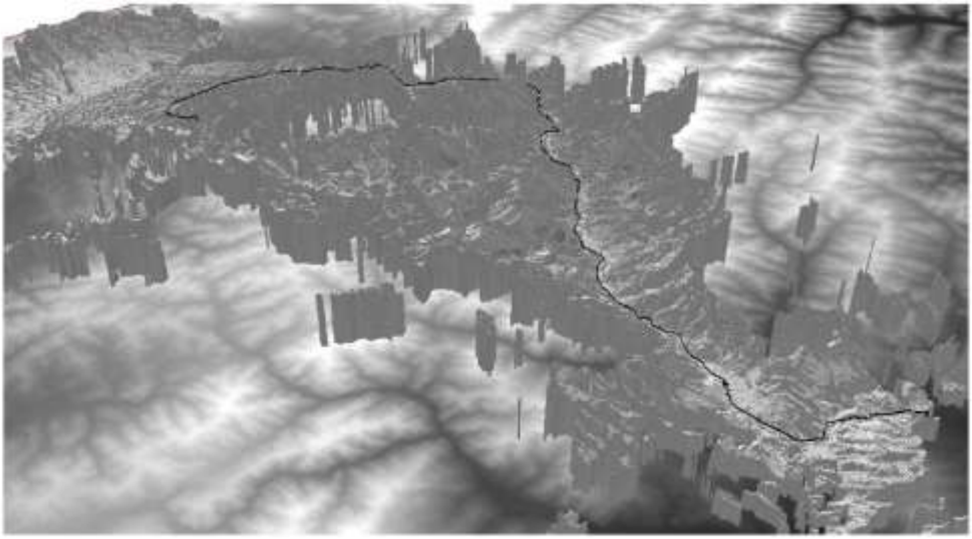

Figure 13. Path 1 3D

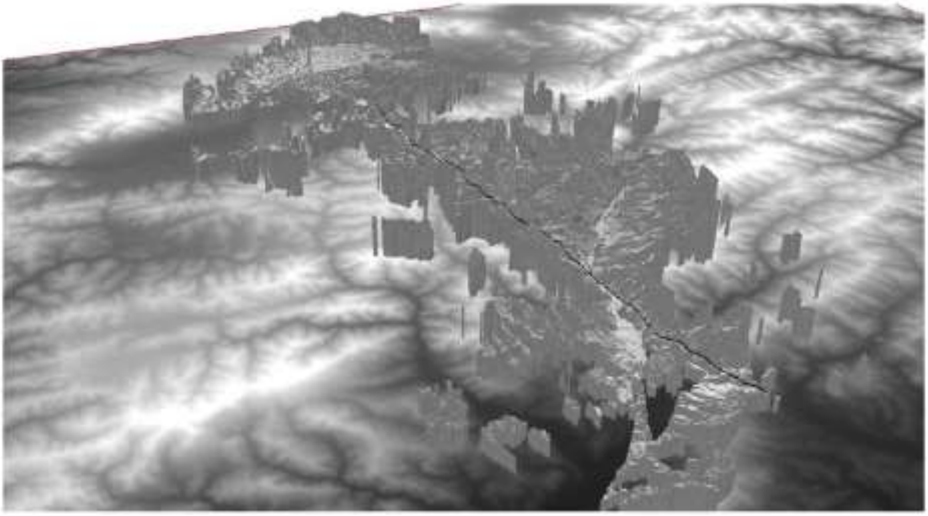

Figure 14. Path 2 3D

Bibliography

Beldiman *et al.* 2012
Beldiman Corneliu, Sztancs Diana-Maria, Buzea Dan-Lucian, *Animale, tehnologie şi artefacte preistorice din materii dure animale descoperite la Păuleni-Ciuc, jud. Harghita. Catalog / Prehistoric osseous materials artefacts discovered at Păuleni-Ciuc, Harghita County. Catalogue / Állatok, technológiá és állati eredetű nyersanyagból készült tárgyak Csikpálfavi (Hargita Megye) lelőhelyról. Katalógus*, Ed. Angustia, Sf. Gheorghe, (2012).

Buzea 2009
Buzea Dan, *Aşezarea eneolitică de la Păuleni. Rolul şi locul ei în cadrul eneoliticului din zona Carpaţilor Răsăriteni*, Teză de doctorat (*ms*), Universitatea "*Lucian Blaga*" Sibiu, (2009).

Buzea, Briewig 2010
Buzea Dan, Briewig Björn, *Experimente arheologice realizate la Păuleni-Ciuc şi Bîile Figa în anii 2007-2009*. In: Memoria Antiqvitatis, XXV-XXVI, Piatra Neamţ, (2010), p. 205- 246.

Buzea, Lazarovici 2005
Buzea Dan, Lazarovici Gheorghe, *Descoperirile Cucuteni-Ariuşd de la Păuleni-Ciuc-Ciomortan „Dâmbul Cetăţii". Campaniile 2003-2005. Raport preliminar*, In: *Angustia*, 9, (2005), p. 25-88.

Cavruc 2000
Cavruc Valeriu, *Noi cercetări în aşezarea Păuleni (1999-2000). Raport preliminar. Prezentare generală*, In: *Angvstia*, 5, (2000), p. 93-102

Cavruc, Dumitroaia 2000
Cavruc Valeriu, Dumitroaia Gheorghe, *Descoperirile aparţi-nând aspectului cultural Ciomortan de la Păuleni (Campaniile 1999-2000)*, In: *Angustia*, 5, (2000), p. 131-154.

Cavruc, Rotea 2000
Cavruc Valeriu, Rotea Mihai, *Locuirea Wietenberg de la Păuleni*, In: *Angustia*, 5, (2000), p. 155-171.

Cavruc, Buzea 2002
Cavruc Valeriu, Buzea Dan-Lucian, *Noi cercetări privind epoca bronzului în aşezarea Păuleni (Ciomortan). Campaniile din anii 2001-2002. Raport preliminar*, In: Angustia, 7, (2002), p. 41-88.

David, Thomas 2008
David Bruno, Thomas Julian, *Landscape Archaeology: Introduction*, in: *Handbook of Landscape* Archaeology, Walunt Creek, (2008).

Dean 1997
Dean Denis J., *Improving the accuracy of forest viewsheds using triangulated networks and the visual permeability method*, Canadian Journal of Forestry, 27, (1997).

Fletcher, Spicer 1988
Fletcher Mike, Spicer Dick, *Clonehenge: an experiment with gridded and non-gridded survey data*, In: Computer and Quantitative Methods in Archaeology, Oxford, (1988).

Gibson 1979
Gibson James, *The Ecological Approach to Visual Perception, Hillsdale*, (1979).

Gillings 2009
Gillings Mark, *Visual Affordance, Landscape, and the Megaliths of Alderney*, Oxford Journal of Archaeology, 28(4), (2009).

Golledge 2003,
Golledge Reginald G., *Human wayfinding and cognitive maps*, In: Colonization of Unfamiliar Landscapes. The archaeology of adaptation, London, (2003).

Hageman, Bennett 2000
Hageman John, Bennet David, *Construction of Digital Elevation models for Archaeological Applications*, In: Practical Applications of GIS for archaeologists: a predictive modeling toolkit, New York, (2000).

Ingold 2000
Ingold Tim, *The Perception of the Environment. Essays on livelihood, dwelling and skill*, London-Routledge, (2000).

Lake *et al*. 1998,
Lake Mark W., Woodman Patricia E., Mithen Steven J., *Tailoring GIS Software for Archaeological Applications: An Example Concerning Viewshed Analysis*, Journal of Archaeological Science, 25, (1998).

Lazarovici, Buzea 2009
Lazarovici Gheorghe, Buzea Dan, *Păuleni-Ciuc (Ciomortan) – Dambul Cetăţii*, In: Lazarovici, Cornelia-Magda; Lazarovici, Gheorghe; Ţurcanu, Senică, *Cucuteni. A Great Civilization of the Prehistoric World* (General Editor: Lăcrămioara Stratulat), Palatul Culturii Publishing House, Iaşi, (2009), p. 130-131, Fig. 1-5.

Lazarovici *et al.* 2000
Lazarovici Gheorghe, Luca Sabin Adrian, Buzea Dan, Suciu Cosmin, *Descoperirile Cucuteni - Ariuşd de la Păuleni*, In: *Angustia*, 5, (2000), p. 103-130.

Lazarovici *et al.* 2002
Lazarovici Gheorghe, Cavruc, Valeriu, Luca Sabin Adrian, Suciu, Cosmin, Buzea Dan, *Descoperirile Eneolitice de la Păuleni. Campania 2001*, In: *Angustia*, 7, (2002), p. 19-40.

Lee, Stucky 1998
Lee Jay, Stucky Dan, *On applying viewshed analysis for determining least-cost paths on Digital Elevation Models*, International Journal of Geographic Information Science, 12 (8), (1998).

Llobera 2000
Llobera Marcos, *Understanding movement: a pilot model towards the sociology of movement*, In: Beyond the Map: Archaeology and Spatial Technologies, Amsterdam, (2000).

2003 - *Extending GIS-based visual analysis: the concept of visualscapes*, International Journal of Geographical Information Science, 17(1), (2003).
2005 - *The Nature of Everday Experience: Examples from the Study of Visual Space*, in: *Re-presenting GIS*, West Sussex, (2005).
2007 - *Modeling visibility through vegetation*, International Journal of Geographic Information Science, 21 (7), (2007).

Riggs, Dean 2007

Riggs Philip D., Dean Denis J., *An Investigation into the Causes of Errors and Inconsistencies in Predicted Viewsheds*, Transactions in GIS, 11(2), (2007).

Sibson 1981,

Sibson Robin, *A brief description of natural neighbour interpolation*, In: Interpreting Multivariate Data, Chichester, (1981), p. XX.

Székély 1970

Székély Zoltán, *Cultura Ciomortan*, In: *Aluta*, 2, (1970), p. 71-76.

Ștefan *et al.* 2010

Ștefan Dan, Ștefan Maria-Magdalena, Constantin Cătălin Petre, *Studiul geomagnetic al fortificaţiilor din epoca bronzului de la Păuleni-Ciuc - Ciomortan "Dâmbul Cetăţii", jud. Harghita*, In: Angustia, 14, (2010), p. 427-436.

Wing, Eklund 2007

Wing Michael G., Eklund Aaron, *Elevation Measurement Capabilities of Consumer-Grade Global Positioning System (GPS) Receivers*, Journal of Forestry 105 (2), (2007).

Wheatley 1995

Wheatley David, *Cumulative Viewshed Analysis: a GIS-based method for investigating intervisibility, and its archaeological application*, In: Archaeology and Geographical Information Systems, London (1995).

Wheatley, Gillings 2002

Wheatley David, Gillings Mark, *Spatial Technology and Archaeology. The Archaeological Applications of GIS*, London, (2002).

Whitlow 2010

Whitlow Raymond, *Archaeological Research at Păuleni-Ciuc, Harghita County*, In: *Angustia*, 14 (2010), p. 413-426.

Whitlow *et al.* 2013

Whitlow Raymond, Kavruk Valerii, Buzea Dan-Lucian, Briewig Björn, *Radiocarbon data from the Cucuteni-Ariuşd levels at Păuleni-Ciuc (Ciomortan)- "Dâmbul Cetăţii", Har-ghita County*, In: *Acta Terrae Septemcastrensis*, 12 (2013), p. 37-64.

ASTER GDEM Validation Team, *ASTER Global DEM Validation Summary Report* (2009), http://asterweb.jpl.nasa.gov/gdem.asp.