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ORIGINAL ARTICLE

Unveiling Site Visibility: A Study of Farming Communities in the Magaliesberg Region, South Africa

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Abstract This paper explores the historical and contemporary significance of visibility in human interactions with their environments, particularly in the context of archaeology and the application of geographic information systems (GIS) for visibility analysis. The study highlights the role of visibility analysis in investigating not only the physical visibility of features in landscapes but also the cultural significance associated with seeing or not seeing them. It draws from the 'visibility relates' principle, which argues that individuals tend to establish connections with visible entities. The focus is on comparing nineteenth-century urban settlements (Kaditshwene, Molokwane, and Marothodi) in the Magaliesberg region of South Africa, particularly examining the strategic positioning of kraals within these Sotho-Tswana farming communities. These settlements are some of the more popular Late Farming Communities (AD 1300–1840) in South Africa; hence, they have archaeological background and are among the few, if not the only ones, that have LiDAR data coverage. The findings reveal distinctions in visibility at both settlement and household scalar levels, with Kaditshwene standing out as different from Marothodi and Molokwane. This suggests that kraals were strategically located to be more or less visible based on specific settlement circumstances, such as attracting people from other communities and concerns about cattle theft. This study contributes to GIS approaches to archaeological sites and landscapes in Africa and calls for more extensive use of geospatial statistics in African archaeology.

Résumé Cet article explore la signification historique et contemporaine de la visibilité dans les interactions humaines avec leur environnement, en particulier dans le contexte de l'archéologie et de l'application des Systèmes d'Information Géographique (SIG) pour l'analyse de la visibilité. L'étude met en lumière le rôle de l'analyse de la visibilité dans l'investigation non seulement de la visibilité physique des caractéristiques des paysages, mais aussi de la signification culturelle associée au fait de les voir ou de ne pas les voir. Elle s'appuie sur le principe des « relations de visibilité», qui soutient que les individus tendent à établir des liens avec des entités visibles. L'accent est mis sur la comparaison des établissements urbains du 19ème siècle (Kaditshwene, Molokwane, Marothodi) dans la région du Magaliesberg en Afrique du Sud, examinant en particulier le positionnement stratégique des kraals au sein de ces communautés agricoles Sotho-Tswana. Ces établissements font partie des communautés agricoles tardives les plus populaires (1300–1840 apr. J.-C.) en Afrique du Sud, d'où leur arrière-plan archéologique et leur couverture en données LiDAR. Les résultats révèlent des distinctions dans la visibilité aux niveaux de l'établissement et du ménage, Kadit-

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shwene se distinguant de Marothodi et de Molokwane. Cela suggère que les kraals étaient stratégiquement situés pour être plus ou moins visibles en fonction des circonstances spécifiques de l'établissement, telles que l'attraction de personnes d'autres communautés et les préoccupations concernant le vol de bétail. Cette étude contribue aux approches SIG des sites archéologiques et des paysages en Afrique, et appelle à une utilisation plus étendue des statistiques géospatiales en archéologie africaine.

Keywords Farming community · GIS · Geospatial · Magaliesberg region · Landscape · Visibility

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Introduction

Throughout history, people have made well-informed decisions concerning where they locate their spaces of use and dwelling to emphasize or inhibit visibility in relation to key features of the surrounding landscape (Smith & Cochrane, 2011; Wright et al., 2014:1 – 2; Verhagen, 2018). Hence, the visibility of, and access to, spaces that are used for dwelling and other various activities has remained a significant subject of interest in understanding human interactions with their surrounding environments. The emergence of digital tools, specifically spatial technologies, has proven to be immensely valuable in studies of past communities and their respective spaces. The application of these tools to investigate landscape visibility in archaeology can be traced back approximately 3 decades ago, when archaeologists first began exploring computer-based methodologies, primarily utilising geographic information systems (GIS) for conducting visibility analysis (e.g., Lake & Woodman, 2003; Wheatley, 1995). Over time, visibility analysis has evolved into one of the most widely employed and popular GIS-based approaches in the field of archaeology.

Archaeological applications have traditionally focused on the experimental aspect of visibility (Verhagen, 2018), wherein visibility is perceived and interpreted as a cognitive and intuitive phenomenon through which human beings make sense of their surrounding environments (Llobera, 2003). Coming on the heels of advances in desktop computing and the integration of GIS into the standard archaeological workflow, Wheatley (1995) was among the pioneers in systematically applying visibility analysis in archaeology. His methods have been subsequently employed to investigate diverse phenomena, including the visibility of monuments (Cummings & Whittle, 2004), defensive sites within landscapes (Smith & Cochrane, 2011), and the visibility of settlements (Grau Mira, 2003). In this way, visibility analysis has served not only to investigate the physical visibility of a location or feature within a landscape but also to deduce the cultural significance associated with seeing or not seeing them—identifying the so-called 'hidden spaces.' The fundamental principle underlying visibility studies is known as 'visibility relates,' which posits that individuals tend to establish connections with visible entities, including other people, features, or places (Kim et al., 2020). Grounded on this premise, scholars have employed visibility analysis to investigate concepts such as patterns of mobility (Llobera, 2020; Llobera et al., 2011; Murrieta-Flores, 2014), choices in settlement locations (Brughmans et al., 2018; Jones, 2006; Zhang et al., 2020), socio-political relationships within communities (Brughmans et al., 2015; Paliou & Bevan, 2016; Prignano et al., 2019), and the phenomenological experience associated with a landscape or monument (Llobera, 2001; Gillings, 2009; Matuszewska & Schiller, 2022). Although visibility analysis faces a significant challenge in terms of its limited sensitivity in identifying and recognising certain morphological aspects of the terrain (Llobera, 2001:1007), the principle of 'visibility relates' offers two key advantages. These include computational efficiency and simplicity during analysis.

Visibility analysis has proven successful in revealing subtle aspects of the landscape in numerous archaeological studies across the world (see Wheatley, 1995; Gillings, 2009; Llobera et al., 2011; Murrieta-Flores, 2014; Brughmans et al., 2018; Llobera, 2020). Conversely, African archaeology has seen limited research in visibility or viewshed analysis (see Wright et al., 2014; Arthur et al. 2019; Sadr & Mshuqwana 2020). In South Africa, Sadr and Mshuqwana (2020) discuss how LiDAR and GIS technologies have improved understanding of the construction sequence and social structure at a stone wall compound in Kweneng, South Africa. Their analysis provides insights into the placement of features, particularly the ash heap outside the main entrances, suggesting that it was intended to impress visitors. The spatial organization of the compound indicates growth over time, with the inhabitants organized into separate family or corporate groups that owned livestock. They posit that the construction of towers prioritized visibility in Kweneng. In East Africa, Arthur et al. (2019) worked with elders from Boreda in southern Ethiopia to document sacred groves, including architectural features, physical settings, and oral histories. Their viewshed analysis using GIS suggests that the sites in the region served defensive purposes, consistent with histories of conflict and resistance to slave raiders. In West Africa, Wright et al. (2014) analyzed archaeological sites in northern Cameroon and compared them with randomly selected sites above 700 m within a given area. Their results indicate that the placement of archaeological sites was not random, but was strategically placed to improve visibility and intervisibility within the surrounding landscape. A Bayesian logical regression model supported their results, rejecting the idea that the sites were randomly selected based on the basis of principles of enhanced visibility.

Sotho-Tswana Farming Communities

The early nineteenth century witnessed a notable concentration of Sotho-Tswana farming settlements as their communities experienced significant growth. Among these settlements, three contemporaneous late farming communities, namely, Marothodi (inhabited by the Tlokwa AD 1815–1823), Molokwane (inhabited by the Kwena AD 1790–1823), and Kaditshwene (inhabited by the Hurutshe AD 1650–1828), emerged in the Magaliesberg region situated in the northwestern interior of South Africa (Fig. 1). These three farming communities were renowned for their large and densely populated agglomerated settlements (Mason 1976; Boeyens, 2003; Anderson, 2009). According to Hall's (2010:152) estimates, Kaditshwene was the most populous at 15,000 residents, followed by Molokwane at 12,000 and Marothodi at 7000. Kaditshwene had the longest recorded occupation, spanning approximately 130 years, while Molokwane was inhabited for around three decades and Marothodi for a relatively shorter period (Boeyens, 2003, 2016). Each of these settlements was organized in a manner where the kraals occupied the central area of each homestead, surrounded by dwellings arranged in a circular or semi-circular fashion (Boeyens & Plug, 2011; Boeyens, 2003; Pistorius, 1996). Following the convention observed in similar sites in southern Africa, the term 'homestead' is

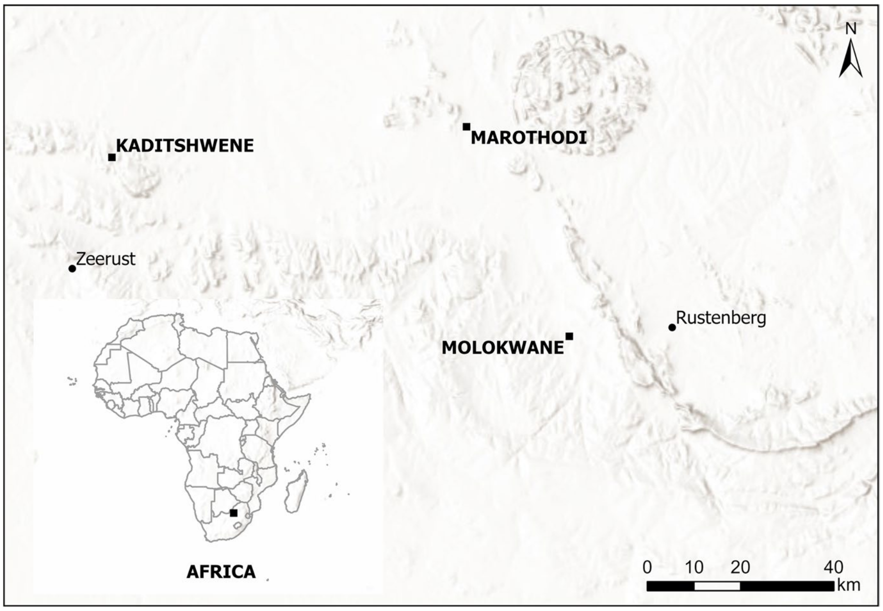

Fig. 1 Map showing the distribution of the three settlements Kaditshwene, Marothodi, and Molokwane and nearby modern towns in the Magaliesberg region, South Africa. Data source: Esri topographic basemap

employed to refer to distinct physical units discernible in the stone-walling configurations of the settlements (Anderson, 2009:94).

Although existing within the same spatio-temporal framework, the three settlements exhibit distinct characteristics. In their comparative study of inequality using the Gini coefficient, with homestead size as an indicator of inequality, Siteleki and Fredriksen (2024) most recently presented evidence showing that, despite having fewer homesteads, Kaditshwene had significantly higher levels of inequality compared to Molokwane and Marothodi. This is noteworthy given that Kaditshwene also had the largest estimated population and was inhabited for a significantly longer period. Siteleki and Fredriksen (2024:16) posit that the Gini coefficient is more effective in highlighting relative disparities in perceptions of insecurity, where location plays a crucial role in settlement organization. The Gini coefficient identified strategies for protecting against violence in unstable and unrestful landscapes, with Kaditshwene located in rugged terrain for defensive purposes (Siteleki & Fredriksen, 2024).

In-depth archaeological investigations have revealed that Marothodi stands out due to the abundant evidence of surplus iron and copper production, which is not observed to the same extent in Kaditshwene and Molokwane (Hall et al., 2006). As recently highlighted by Klehm (2017:604), within the Late Farming Communities (AD 1300–1840) of southern Africa, the rise in social stratification is interpreted as an indication of increased production, surplus, labor specialization, control over the political economy, expansion of political territorial influence, sedentism, urbanism, and globalization. Reflecting the diverse specialization within an increasingly dense political landscape, Boeyens (2003) presented a compelling argument that the emergence of large farming communities in southern Africa was influenced by factors such as inter-chiefdom conflicts, population growth, drought, the accumulation of cattle, and the centralization of political power (Huffman, 1996; Mason, 1974). With conflicts (e.g., especially Kaditshwene and its neighboring settlements in the west) and the resulting instability in societies, cattle theft and raiding were a common occurrence in southern Africa (Comaroff & Comaroff, 1990; Boeyens, 2003, 2006; King, 2017).

Cattle played a vital role among these farming communities as symbols of wealth and social status. They also served as means of transportation for goods and were utilized in the production of shields and karosses using their skins (Boeyens, 2003, 2016; Comaroff & Comaroff, 1990; Huffman, 1986a, 1986b, 2014). Cattle were housed in kraals located within the *kgosing* (see explanation below), with cattle husbandry becoming increasingly prominent after approximately AD 1700 (Maggs 1976; Huffman, 1996; Fredriksen & Chirikure, 2015:7). The term *kgosing* (Setswana/Sesotho language) specifically denotes the section of the settlement inhabited by the king and his lineage, excluding the non-royal spaces of the community (Pistorius, 1996:149). Due to the elevated status, power, and wealth associated with cattle ownership, their numbers exceeded those of sheep and goats (Ndobochani, 2020). The importance of cattle can be seen in its role in significant events or ceremonies that include weddings, infant socialization, rites, burial/funeral practices, and inheritance (Comaroff & Comaroff, 1990; Matjila & Haire, 2008; Morton & Hitchcock, 2014; Schapera & Comaroff, 2015). Typically, the elite among farming communities considered cattle to be a valuable social and economic asset that required protection (Ndobochani, 2020:264).

It is from this background that this study is the first to compare the visibility of kraals in different nineteenth-century urban settlements, Marothodi (MRT), Kaditshwene (KDS), and Molokwane (MLK), in the Magaliesberg region in South Africa. A kraal refers to an enclosure, typically situated at the center of the settlement, where livestock, particularly cattle, are kept (Badenhorst, 2009:148). The term kraal originates from the Afrikaans language and is employed in this paper due to its widespread usage within the discourse on the ‘Iron Age’ (i.e., Farming Communities) in South Africa. In the Sesotho language, a kraal is referred to as ‘lesaka’. Kraals are known to be typically surrounded by buffalo grass in southern Africa, which makes them visible on aerial photographs (Denbow, 1979, 1982). In comparing kraal visibility, this research poses the question: were kraals—important locales among Sotho-Tswana farming communities—strategically located to be more or less visible in the landscape? Bearing in mind this question, the following hypothesis is formulated.

Null hypothesis: the three groups are from the same populations/the average visibility of the kraals and random kraals from the raster surface of MRT, MLK, and KDS is the same.

Alternative hypothesis: at least one of the groups is different/the average visibility of the kraals and random kraals from the raster surface of MRT, MLK, and KDS is not the same.

Given the substantial size, intricate design, and labor invested in constructing these homesteads and kraals, it is pertinent to investigate whether their placement was deliberate to optimize visibility both within and around the settlements. GIS tools, including visibility analysis, and statistical techniques such as Kruskal–Wallis enable the investigation of whether features situated at similar or different elevations were strategically positioned to facilitate mutual visibility. Marothodi, Molokwane, and Kaditshwene are some of the most studied archaeological sites in South Africa; hence, they have the archaeological background from which to situate findings from this research. Importantly, LiDAR coverage required for this study is currently limited to these three settlements.

Methodology

Visibility analysis is employed to examine the visibility of specific places, locations, or physical objects within a given landscape, aiming to pinpoint precise areas of land visible from a given point (Wheatley & Gillings, 2002:201; Kim et al., 2020:1). This computational technique determines the visibility of raster surface positions or locations to a designated group of observers. Raster data refer to geographic data presented as a matrix of cells, with each cell containing an attribute value (Esri, 2023). Conversely, vector data represent geographic features as points, lines or polygons (Esri, 2023). LiDAR imagery was used as the raster surfaces. LiDAR, Light Detection and Ranging, is a remote sensing method that utilizes pulsed laser technology to examine and generate highly detailed models of the Earth's surface (National Oceanic and Atmospheric Administration 2023). In essence, visibility analysis determines which observer features are visible from each raster surface location. The visibility of each cell center is determined by comparing the altitude angle to the cell center with the altitude angle to the local horizon (Esri, 2023). The local horizon is computed by considering only the terrain (i.e. not 24 vegetation) between the observation point and the current cell center. If the point lies above the local horizon, it is considered visible. In ArcMap software, visibility analysis involves two parameters: frequency and observer (Esri, 2023). Frequency determines which raster surface locations are visible to the observer features, and the output records the number of times each cell location in the input raster surface can be seen by the observer features. On the other hand, the observer parameter identifies the locations from which observers are visible within each raster surface. Therefore, in this study, the kraals were used as the input observer features, while LiDAR imagery served as the input raster surface.

To address the research inquiry, the kraals and homesteads were digitized as vector data on LiDAR images, with previous archaeological research as ground truth for comparison. The vector data were then employed to conduct visibility and viewshed analyses. The LiDAR images also were utilized to estimate the elevation of the kraals and homesteads.

Data and Digitization

The LiDAR data of Kaditshwene and Marothodi was collected by SMG, courtesy of the University of Cape Town. Southern Mapping Geospatial (SMG), a private company, conducted a LiDAR survey with the aim of generating rectified color images and a digital terrain model (DTM) for both settlements. Combined, Kaditshwene and Marothodi encompass an area of approximately 1855 ha. The survey flight occurred on the 24th and 26th of June in 2016, during which the LiDAR system scanned the ground at a laser frequency rate of 100 kHz from an altitude of around 600 m (SMG 2016). This process yielded a detailed DTM capturing the surface of the ground and objects above it. Additionally, the digital color images were captured from the aircraft and rectified to produce color orthophotos with a pixel resolution of 10 cm. The weather conditions during the flight days were characterized by haze and scattered smoke. Notably, no ground control points were established for this particular LiDAR survey. Molokwane underwent surveying under the auspices of the University of the Witwatersrand on the 5th of November 2015 (SMG 2015). The survey resulted in the production of rectified color images alongside a DTM. During the survey, the LiDAR system employed a laser frequency rate of 150 kHz to scan the ground, yielding a detailed DTM of both the ground surface and objects situated above it. The aircraft operated at an altitude of approximately 700 m, capturing digital color images that were subsequently rectified to generate color orthophotos with a pixel resolution of 7 cm. Weather conditions during the survey were characterized by clear, sunny skies. With the resulting LiDAR images, ground features such as vegetation do not obstruct the visibility of the stone-walling.

The stone-walling examined in this project was compared to previous scholarly investigations, where extensive field work and ground truthing was conducted. Marothodi settlement was contrasted with Mark Anderson's doctoral dissertation, published in 2009. In 2013, Anderson expanded on the topic with a book (see Anderson, 2009 and 2013 on reference list). Molokwane settlement was evaluated in relation to Julius Pistorius' research conducted in 1994, and his work on spatial expression in the *kgosing* of Molokwane in 1996. Similarly, the stone-walling of Kaditshwene was compared to Jan Boeyens' research on Kaditshwene in 2000 and 2003.

The walls of the settlements were digitized from the DTM using the 'Vetorise' tool in Arcmap software 10.8 and then edited by hand where necessary after having consulted detailed ground-truthed walls in Kaditshwene (Boeyens 2000, 2003), Molokwane (Pistorius 1994, 1996), and Marothodi (Anderson, 2009, 2013).

Computation Elevations

In order to conduct visibility analysis and elucidate positioning within the landscapes, the elevation of the kraals and homesteads (i.e., vector data) was determined. This encompassed assessing the amount of space allocated for housing the cattle within the kraals. In ArcMap software version 10.8, the elevation data for each kraal and homestead at the center was obtained by extracting cell values from the LiDAR images based on the point locations of the kraals and homesteads. This was done using the 'Elevation Point From DEM' tool, which adds elevation points where one clicks on the map. Subsequently, the average or mean elevation of the kraals and homesteads within each settlement was estimated. With the aim to determine whether kraals were intentionally positioned as prominently visible features within the sites at the settlement scalar level, vector points were used to represent the kraals (typically positioned in the center) so that the 'Create Random Points' tool could be used. Future research can explore running this analysis with polygons/polylines at different scales.

Visibility at the Settlement and Household Scalar Levels

When performing visibility analysis using ArcMap software (10.8), the surface offset, which refers to the vertical distance value added to the *z*-value of the raster surface cells (Esri, 2023), was set to the average elevation of the kraals. The observer elevation was then established as 1 m above the surface elevation. This 1 m value represents the average height of the stone-walling found in all the settlements, with the aim to standardize the analysis, since the wall heights are known in some settlements but not in others. Initially, the visibility analysis was set at the settlement scalar level, a 650-m radius or limit range around the center of the kraal clusters (Fig. 2). It could be argued that a 650-m radius is relatively small. However, this distance was chosen to standardize the analysis due to variations in the areal coverage of LiDAR imagery across different settlements, which impose restrictions on the settlement scalar level radius. To focus the visibility analysis of the *kgosing* area where the kraals are typically situated within the settlements, the scale was reduced to 10×25 m at the household scalar level for intra-site analysis.

At the settlement scalar level of visibility analysis, the objective was to determine whether the kraals were intentionally positioned as prominently visible features within the settlements. Therefore, the visibility of the kraals was compared to a set of ten randomly selected non-kraal points (referred to as random kraals/RK) in the landscape to ascertain if the kraals exhibit significantly higher visibility compared to other stone-walling features. Drawing from Wright et al. (2014), ten randomly selected sets to compare to the actual are sufficient to accept or reject the null hypothesis with a high level of confidence. The random points representing the random kraals were generated using the 'Create Random Points'

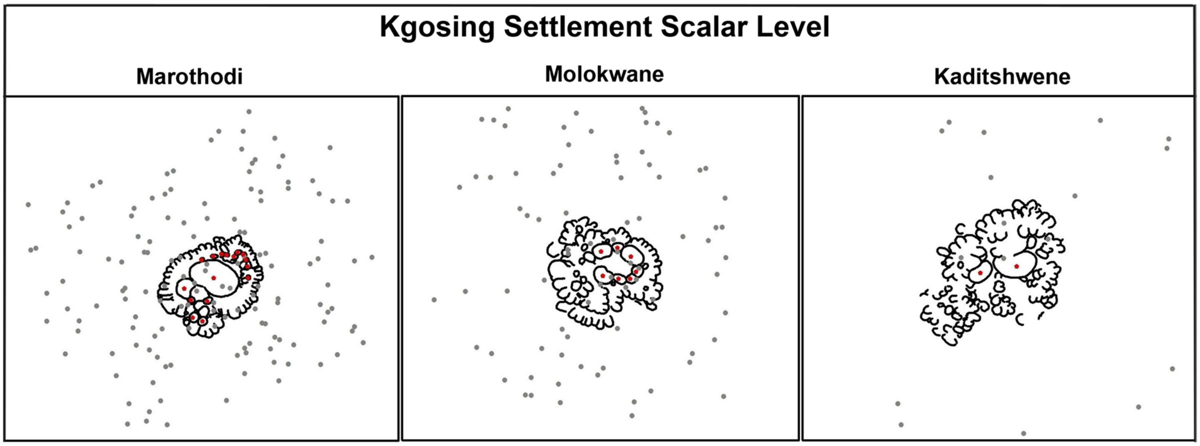

Fig. 2 The thick semi-circular lines represent *Kgosing* and are surrounded by random kraal (RK) points at Marothodi, Molokwane and Kaditshwene at the settlement scalar level (at a spatial scale of 650 m, respectively). Kgosing is digitized as explained in "Data and digitization"

tool in ArcMap software (10.8). The visibility analysis was conducted on ten datasets (i.e. random kraals) at the settlement scalar level (see Fig. 2 for a representative selection of maps displaying random non-kraal points). It is important to note that the kraals themselves are not points but polygons. However, the observed locations for visibility analysis are considered as points at this scalar level.

The analysis was initially performed on the actual locations of the kraals within each settlement, followed by conducting the analysis on the ten sets of random kraals. This multiple iteration approach was necessary to determine the statistical significance of any observed differences (Wright et al., 2014). The random kraal points used for comparison were randomly generated points that corresponded to the same number of kraals within each settlement, positioned within the outer walling that demarcates the limits of each settlement. For instance, in the case of Molokwane, which has eight kraals, eight random non-kraal points were created ten times specifically for Molokwane. The same procedure was followed for Kaditshwene and Marothodi, respectively.

Subsequently, the visibility scale was reduced to a smaller household scalar level, focusing on an approximate range of 10 by 25 m surrounding the outer walling of each *kgosing*. The intra-site visibility analysis was conducted within the household scalar level (refer to Fig. 3) using the Viewshed technique in ArcMap software (10.8), utilising the 'Observers' tool on the LiDAR imagery (Esri, 2023). In this analysis, the outline of each kraal was used as the input for observers instead of using points, providing a more realistic and accurate representation for further examination and analysis.

Statistical Inputs

Through visibility analysis, it is possible to examine the settlements in greater detail focusing on the inter-connections between homesteads and kraals at a closer level. The Kruskal–Wallis test was used to further contextualize the visibility data and to contribute to a comprehensive understanding of the visibility dynamics within the settlements. The Kruskal–Wallis non-parametric test was employed to assess the significant difference among multiple independent groups (Pohlert, 2014, 2016). These groups, regardless of their size, can either be identical or diverse. As a non-parametric test, the Kruskal–Wallis does not rely on assumptions regarding the data distribution, thereby avoiding any distribution assumptions. This statistical technique was used to determine whether the visibility of kraals is a random product of the landscape or not. In determining this, the Kruskal–Wallis technique statistically compared the visibility of the kraals with the ten sets of random kraals with elevation as a variable using RStudio software version 12.1. Of course, other variables such as slope can be explored but that is beyond the scope of

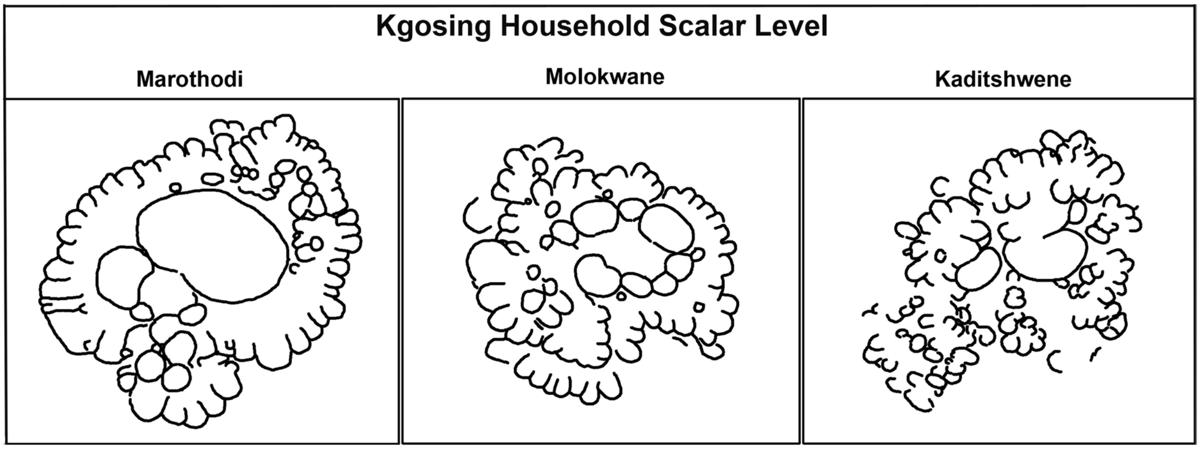

Fig. 3 Visibility in Marothodi, Molokwane and Kaditshwene *Kgosing* at the household scalar level (at a spatial scale of 10×25 m, respectively). Kgosing is digitized as explained in "Data and digitization"

this paper, which focuses on visibility hence elevation is more relevant. The outcomes of this statistical test were analyzed and interpreted in relation to the hypothesis formulated in the introduction, enhancing the understanding of the research findings.

Results

This section presents the findings of the visibility analysis conducted at the settlement and the household scalar levels. The objective was to investigate whether the placement of kraals, which held significant importance among the Sotho-Tswana farming communities, led to varying levels of visibility throughout the landscape. Table 1 provides the recorded elevation values of the kraals and homesteads in Marothodi, Molokwane, and Kaditshwene, derived from the LiDAR images.

Table 1 Elevation of kraals and homesteads in the Magaliesberg region

Settlement	Average elevation (m): kraals	Average elevation (m): homesteads
Marothodi	1135	1138
Kaditshwene	1373	1373
Molokwane	1190	1194

Visibility at the Settlement Scalar Level

The comparison between the actual kraals and randomly placed kraals provides valuable insights into the visibility analysis conducted at the settlement scalar level. The visibility maps show the level of visibility (high, low) of the kraal vector from the raster surface, i.e., locations from which kraal vectors are visible within each raster surface.

In Marothodi (Fig. 4), when observing the eastern direction from the kraal cluster, it becomes apparent that two kraals exhibit significantly higher visibility compared to the rest of the cluster. Generally, the visibility of the remaining kraals is moderately low. In Molokwane (Fig. 5), the central cluster of kraals exhibits high visibility in the immediate vicinity, but as one moves further away, the visibility decreases substantially.

Kaditshwene, on the other hand, exhibits a distinct pattern. The two kraals in Kaditshwene are only visible within close proximity to their respective locations, and they become more invisible (with low visibility) when observing the surrounding area at the settlement scalar level (Fig. 6). The findings are also presented in terms of area coverage to gain a different perspective and understanding of the implications of visibility and non-visibility in relation to spatial utilization. The areas of visibility and non-visibility are determined based on the cells of the LiDAR imagery representing the surface and are expressed in square meters (m^2) in Table 2, as this

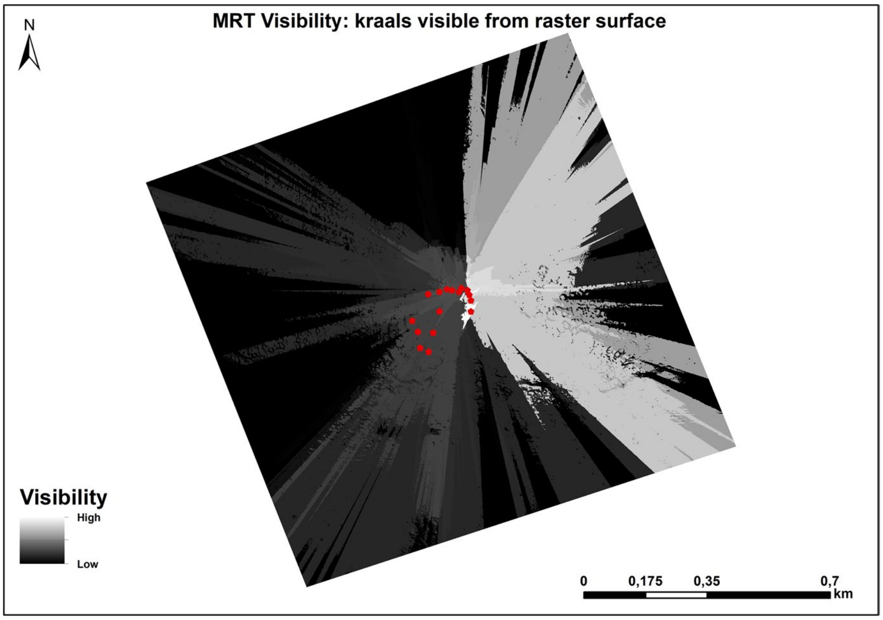

Fig. 4 Visibility analysis of the kraals in Marothodi with the (actual) kraals at the settlement scalar level. The color black represents a low visibility of the kraal vectors as points from the raster surface, while light grey/white represents a high visibility of the kraal vectors from the raster surface as generated from the visibility analysis tool in Arcmap (see "Methodology" for input parameters)

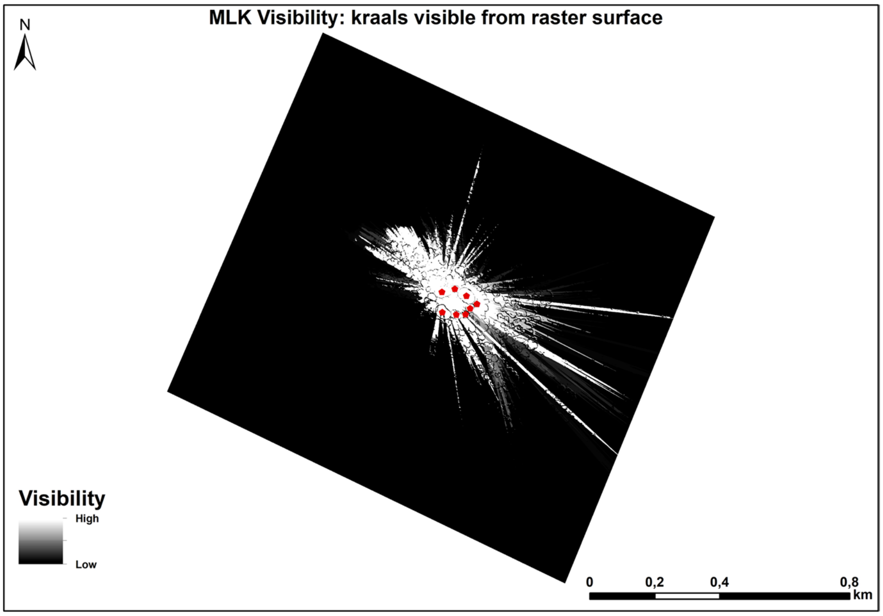

Fig. 5 Visibility analysis of the kraals in Molokwane with the (actual) kraals at the settlement scalar level. The color black represents a low visibility of the kraal vectors as points from the raster surface, while light grey/white represents a high visibility of the kraal vectors from the raster surface, as generated from the visibility analysis tool in Arcmap (see "Methodology" for input parameters)

provides a more informative way to comprehend and interpret the results. In Marothodi, the kraals are visible across 99.5% of the entire 1327 ha area, with only 0.43% of the area being non-visible.

The kraals in Molokwane exhibit visibility across a mere 6.39% of the 1327 ha area at the settlement scalar level, while most of the area (93.6%) is characterized by non-visibility. Overall, the kraals in Molokwane are less visible within the landscape, as depicted in Fig. 6 and Table 3. Similarly, in Kaditshwene, the kraals display high visibility in a very small portion of the area (0.35%) at the settlement scalar level, while the remaining 99.6% of the 1327 ha area shows non-visibility.

The values presented in Tables 2 and 3 demonstrate a reasonable relationship between the visibility of kraals in the landscape and their respective sizes. Despite Marothodi being the smallest settlement

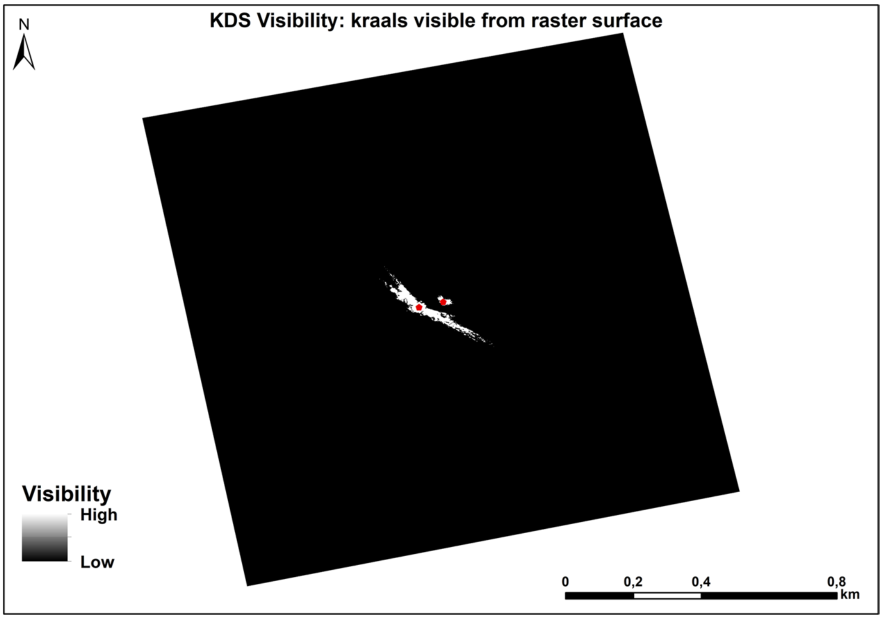

Fig. 6 Visibility analysis of the kraals in Kaditshwene with the (actual) kraals at the settlement scalar level. The color black represents a low visibility of the kraal vectors as points from the raster surface, while light grey/white represents a high visibility of the kraal vectors from the raster surface, as generated from the visibility analysis tool in Arcmap (see "Methodology" for input parameters)

Table 2 Visibility based on the true location of the kraals in the region in terms of area (m^2) and percentage (%). NB: this presents the visibility data in terms of areas that are visible and non-visible

		Visibility from the true location of the kraals		
Settlement	Visible (m^2)	Visible (%)	Non-visible (m^2)	Non-visible (%)
Marothodi	1,593,158.43	95.5	6922.009	0.43
Molokwane	182,794.43	6.39	2,676,933.12	93.6
Kaditshwene	7196.61	0.35	2,041,943.91	99.6

compared to Molokwane and Kaditshwene, it boasts the largest number of kraals, totalling 13.953.92 m^2. Conversely, Kaditshwene, being the largest settlement in size, only accommodates two kraals, amounting to 5.090.23 m^2. Molokwane falls in between with its kraals encompassing an area of 7.166.35 m^2. These findings highlight the variation in kraal size across the settlements and provide insight into their spatial distribution and visibility.

Visibility at the Household Scalar Level

The ensuing maps depict the visibility of kraal outlines, both from the vicinity of the dwelling structures and from various locations across the raster surface. The color gradient ranging from brown to blue/green illustrates the varying degrees of visibility of the outline (i.e. stone-walling) of the kraal vectors. The shades of brown indicate higher visibility, whereas the blue/green shades signify lower visibility.

Marothodi and Molokwane exhibit similarities in terms of viewshed analysis, as the outlines of the kraals are visible both from within and outside the kraals (refer to Figs. 7 and 8), as well as from the surrounding areas of the settlements. In contrast, Kaditshwene presents a different scenario, where the kraals are solely visible from the southwestern part of the settlement and in close proximity to the settlements (see Fig. 9).

Statistical Inputs

The Kruskal–Wallis test provides statistical context to the findings of the levels of visibility of kraals and random kraals (Table 3).

Table 3 Visibility of the random kraals in the region (in area m^2 and %)

Settlement	RK1	RK2	RK3	RK4	RK5	RK6	RK7	RK8	RK9	RK10
					m2					
MRT	1,600,080.80	1,586,750.62	1,600,079.36	1,533,966.14	1,600,079.62	1,600,079.23	1,600,071.86	1,600,079.14	1,600,063.33	1,600,079.23
MLK	186,319.38	2,343,224.62	188,104.76	317,672.62	638,849.38	114,708.766	1,148,434.77	284,949.64	570,816.87	310,910.95
KDS	10,486.07	429,543.20	48,181.73	955.35	92,679.62	272,533.11	1,058,335.05	21,679.90	1,240,254.36	13,141.73
					%					
MRT	99.9	99.1	99.7	99.1	99.7	99.7	99.6	99.7	99.5	99.7
MLK	11.42	18	11.53	19.48	39.19	7.03	70.44	17.47	35.01	19.07
KDS	0.51	20	2.35	0.04	4.52	13.29	5.16	1.05	60.52	0.63

Based on the *p*-values, there is a statistically significant association between variables for the Marothodi settlement meaning there is sufficient evidence to reject the null hypothesis, but not for the Molokwane and Kaditshwene settlements.

Discussion

Visibility analysis is typically interpreted in the context of perceiving and comprehending physical space. Therefore, it serves as a valuable tool for investigating the cultural and social significance associated with the act of seeing or not seeing certain features. Since individuals tend to establish connections with visible objects, people, and characteristics, the visibility of a particular feature holds greater importance compared to those that are not visible. Upon examining Table 1, a discernible pattern emerges, revealing a correlation between the elevation of the homesteads and kraals, as they occupy relatively similar altitudes. This pattern could be attributed to the inhabitants' intentional desire to enhance their visibility and intervisibility within the surrounding landscape, similar to those in Kweneng as shown by Sadr and Mshuqwana (2020). This could be a desire to display wealth, since it is common that the houses of the elite tend to be larger, costly, and more elaborate compared to those of commoners in hierarchical societies in southern Africa (see Huffman, 1986a; Bodley, 2003:97). Furthermore, research (Kohler et al., 2018) has shown that increases in house size can be correlated with increases in wealth or income. In the context of southern Africa, a typical hypothesis derived from ethnographic accounts would be that a wealthier man could afford more wives and have more children and would therefore require more and larger homesteads.

In this study, it was crucial to determine the specific areas within the landscape from which observers, kraals, are visible. This information is essential for understanding whether cattle—a valuable resource—were possibly intentionally concealed or not. Importantly, one must bear in mind that the visibility of a landscape feature does not automatically guarantee access to that particular feature. The inhabitants of the settlements may perceive and interact with their surroundings based on their everyday experiences. When comparing the visibility of kraals among the

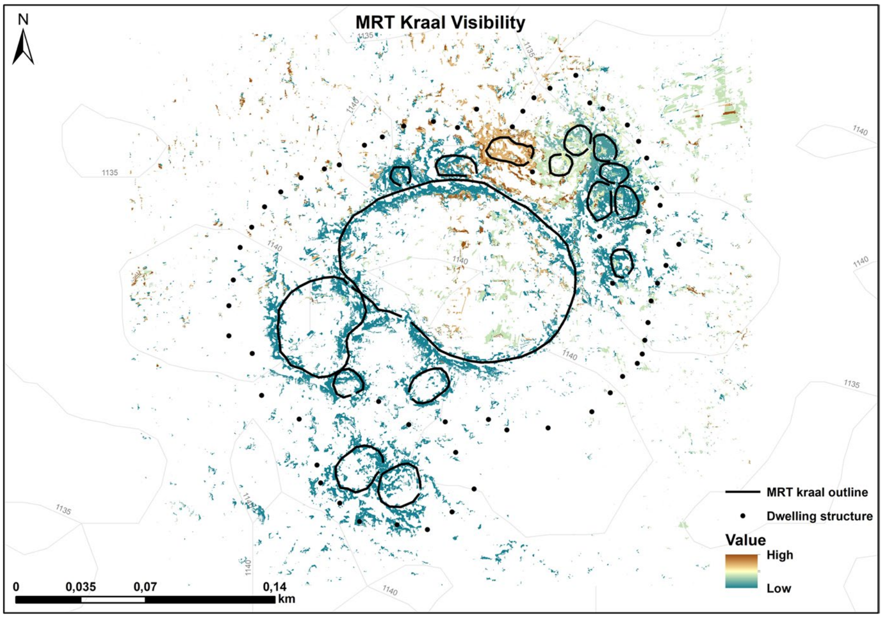

Fig. 7 Viewshed in Marothodi. This map shows the degree of visibility of the kraal vector outline (high, low) from the surrounding dwelling structures and raster surface at the household scalar level. The color blue/green represents a low visibility of the kraal vectors as lines from the dwelling structures, while brown represents a high visibility of the kraal vectors from the dwelling structures, as generated from the Viewshed analysis tool in Arcmap (see "Methodology" for input parameters)

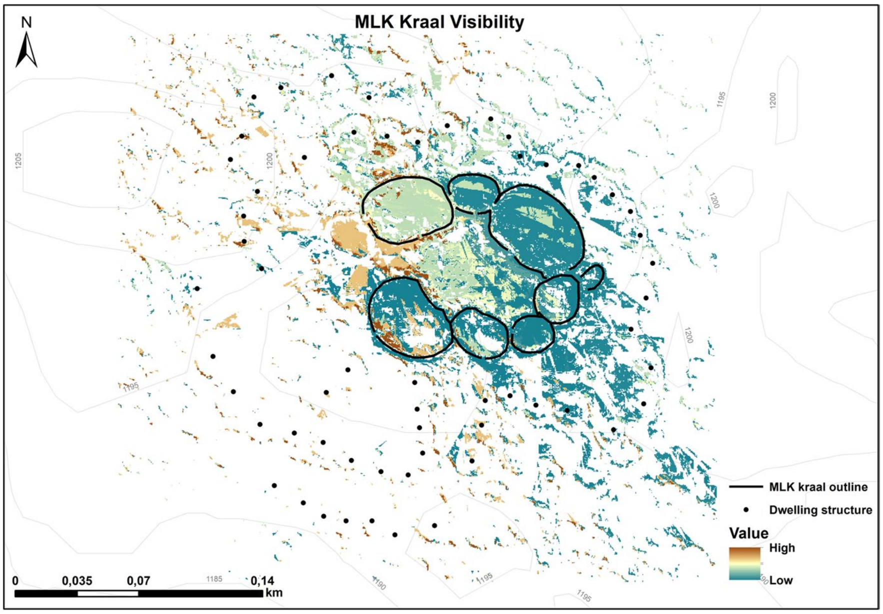

Fig. 8 Viewshed in Molokwane. This map shows the degree of visibility of the kraal vector outline (high and low) from the surrounding dwelling structures and raster surface at the household scalar level. The color blue/green represents a low visibility of the kraal vectors as lines from the dwelling structures, while brown represents a high visibility of the kraal vectors from the dwelling structures, as generated from the Viewshed analysis tool in Arcmap (see "Methodology" for input parameters)

three settlements, it becomes apparent that Marothodi kraals are the most visible from the surrounding landscape, followed by Molokwane kraals and finally Kaditshwene kraals, which exhibit the least visibility. The kraals in Kaditshwene are scarcely visible from the surrounding environment, which suggests a deliberate effort by the Hurutshe community to keep out of sight and protect their valuable social and economic asset—cattle. Despite Kaditshwene being the largest settlement, it had only two kraals, whereas Marothodi, a considerably smaller settlement with an estimated population less than half that of Kaditshwene, had eighteen kraals. This discrepancy may explain why the kraals in Marothodi were more visible compared to those in Kaditshwene. Marothodi may have had more visible kraals given that its focus was on copper and iron production by the Tlokwa community. More kraals in Marothodi could have housed the cattle they

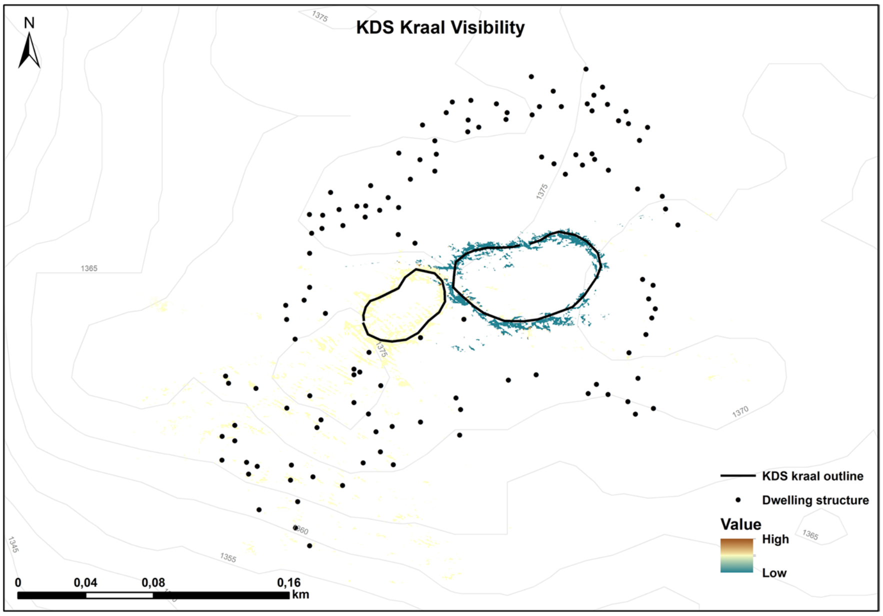

Fig. 9 Viewshed in Kaditshwene. This map shows the degree of visibility of the kraal vector outline (high and low) from the surrounding dwelling structures and raster surface at the household scalar level. The color blue/green represents a low visibility of the kraal vectors as lines from the dwelling structures, while brown represents a high visibility of the kraal vectors from the dwelling structures, as generated from the Viewshed analysis tool in Arcmap (see "Methodology" for input parameters)

Table 4 Kruskal–Wallis output from using elevation as a variable

Settlement	*p*-value	Chi-squared	Df
MRT	0.001318	28.85	10
MLK	0.08278	16.638	10
KDS	0.1607	14.277	10

received through trading iron and copper with neighboring communities.

Looking at the visibility analysis at the settlement scalar level, the placement of kraals in Marothodi was perhaps intended to maximize visibility, whereas the same is not observed for Molokwane and Kaditshwene. At the household scalar level, which is represented by the perimeter of the homesteads, the visibility of kraals to the dwelling structures varies. Like at the settlement scalar level, Kaditshwene exhibits the lowest visibility to the neighboring homesteads compared to Marothodi and Molokwane. From the Kruskal–Wallis analysis, the null hypothesis is rejected for Marothodi settlement, indicating that the average visibility of kraals and random kraals from the raster surface is different in this settlement. For the Molokwane and Kaditshwene settlements, the null hypothesis is not rejected (i.e. fail to reject), suggesting that there is not sufficient evidence to conclude that the average visibility of kraals and random kraals differs significantly in these settlements. It is important to note that there might be some trends in the data for further exploration, especially in the case of the Molokwane settlement where the p-value is relatively close to the significance threshold. While the three settlements have the same degrees of freedom, indicating the same level of flexibility in the analysis, the chi-squared values vary. Marothodi settlement exhibits the greatest deviation from expected frequencies, followed by Molokwane and then Kaditshwene. This suggests that Marothodi settlement has the most significant differences in average visibility compared to the others, while Molokwane shows relatively fewer differences (with a *p*-value close to the threshold) and Kaditshwene relatively shows the least differences. These findings indicate that a larger spatial scale and sample of random kraal points is necessary to establish with certainty whether kraals were intentionally positioned to enhance visibility from the surrounding areas.

Considering the success and popularity of Kaditshwene, it is possible that the kraals in this settlement were intentionally concealed due to the influx of individuals seeking to join the community. However, it is worth noting that Kaditshwene also faced significant conflicts with communities from the western region, now known as Botswana (Boeyens, 2003, 2016). Concealing the kraals may have been a preventive measure against cattle theft, which was prevalent during that time (King, 2017). It was common for the wealthiest settlements to become impoverished after raiders stole their cattle, but they could regain wealth by retaliating and reclaiming the stolen cattle. Given the population growth, conflicts, centralising of power, and accumulation of cattle (as mentioned earlier), cattle raiding can be seen as being a result of economic, political, and social pressure as people were often having to leave their more stable and predictable lifestyle and environments to seek shelter in less stable environments and thereby becoming raiders themselves (King, 2017).

Importantly, visibility operates on a dual axis, since being seen could also imply the capacity to perceive one's surroundings. Consequently, enhancing visibility may have served as a defensive tactic aimed at safeguarding a particular settlement from potential ambush. Sotho-Tswana farming communities used the landscape to their advantage in building their settlements. They would strategically place their settlements on hilltop positions that they could easily and readily defend from potential conflict (Hall, 1995). Inhabited for a longer timespan (approximately 130 years), the Hurutshe of Kaditshwene would have had to position themselves strategically on the landscape to protect themselves and their resources more-so compared to the Tlokwa who inhabited Marothodi for a short period (almost a decade), with a focus on producing iron and copper.

Despite these three settlements in the Magaliesberg region existing within the same period, they exhibit different patterns of kraal visibility. In comparing kraal visibility, it can be noted that the kraals—important locales among Sotho-Tswana farming communities—were strategically located to be more visible in Marothodi and less visible in Molokwane, and even less so in Kaditshwene. Kaditshwene is indeed a unique settlement in this region. This can be supported by the comparative study of inequality where Kaditshwene also was different with its high levels of inequality and location on rugged terrain for defensive purposes.

Concluding Remarks

Kaditshwene stands out as distinct from Molokwane and Marothodi in terms of visibility at both the settlement and household scalar levels. Kraals, as significant locales within the Sotho-Tswana farming communities, were strategically positioned to be more or less visible in the landscape depending on the specific circumstances of each settlement. In the case of Kaditshwene, the kraals were situated to be less visible, likely due to the settlement's success in attracting people from other communities, as well as the concern for potential cattle theft. Furthermore, unlike the kraals, the overall settlement of Kaditshwene was located at a higher elevation compared to Marothodi and Molokwane. Conversely, the kraals in Marothodi were intentionally situated to be more visible than those in Kaditshwene. This distinction can be attributed to the prioritization of copper and iron production over cattle in Marothodi, although cattle remained important in the community. Molokwane kraals and random kraals are in-between Marothodi and Molokwane given a p-value that is close to significance.

Importantly, since the radius of analysis was constrained by the availability and extent of LiDAR coverage, future research should focus on a larger landscape and spatial scale thus allowing for the inclusion of more kraals and random kraals, and potentially kraals as polygons. Nevertheless, this paper marks the initial step towards exploring the comparative visibility and positionality of homesteads and kraals in farming communities of southern Africa. This is a key study that contributes to the scarce studies on GIS visibility approaches to archaeological sites and landscapes in Africa, since it is clear that there needs to be more use of geospatial statistics in archaeological landscape studies in Africa.

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