Monumental funerary landscapes of Dhar Tagant (south-eastern Mauritania): Towards ethical satellite remote sensing in the West African Sahel

Gonzalo J. Linares Matás1,2 | Jonathan S. Lim2,3

1St. Hugh’s College, University of Oxford, Oxford, UK
2School of Archaeology, University of Oxford, Oxford, UK
3St. Cross College, University of Oxford, Oxford, UK

Correspondence
Gonzalo J. Linares Matás, St. Hugh’s College, University of Oxford, St Margaret’s Road, Oxford OX2 6LE, UK.
Email: gonzalo.linaresmatas@st-hughs.ox.ac.uk

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Abstract
The remembrance of the dead is a ubiquitous dimension of most human societies, and the spatial dimension of mortuary practices actively constitutes an essential element of the cultural significance of certain places in the landscape. The visual prominence of stone-built funerary monuments in dry upland areas is particularly conducive to their multiscalar study through above-ground remote sensing methods. In this paper, we characterize the nature and distribution of Late Holocene drystone funerary monuments in the Dhar Tagant region of south-eastern Mauritania using freely available, very high-resolution (VHR) satellite imagery. We contextualize them in relation to the monumental mortuary records of Senegal and Mali within the West African Sahel, exploring their similarities and differences with other monumental funerary landscapes in semi-arid environments. Ethical considerations and a self-reflective attitude must be at the forefront of archaeological research, and we discuss the ethics of remote sensing research in the study of funerary practices in Africa, as well as the opportunities and challenges for remote collaborative engagement with local communities in the context of fieldwork restrictions.

KEYWORDS
Bing Maps, funerary tumuli, GIS, multivariate statistics, Tichitt Tradition, viewshed analysis

1 | INTRODUCTION

The Covid-19 public health emergency is accelerating current efforts to rethink how research in a predominantly field-based discipline such as archaeology is conducted (Ogundiran, 2020; Scerri et al., 2020). A considerable reduction in survey costs, the synoptic view afforded and the non-invasive nature of remote sensing provide an attractive, comprehensive and suitable method to approach the study of cultural landscapes, proving particularly successful in the survey of vast, underexplored and/or politically unstable territories across the globe, from tropical jungles to deserts (Harrower & Comer, 2013; Lasaponara & Masini, 2012; Parcak, 2009; Schaber & Gumerman, 1969; Schmidt, 1940; Wiseman & El-Baz, 2007).

Very high-resolution (VHR) digital satellite imagery achieves sub-1 metre ground sampling distance (GSD) under good conditions, which allows investigators to locate and characterize a wide range of archaeological features (Bewley et al., 2016; Rayne et al., 2017). In the central Sahara, the combination of WorldView 2 (with a resolution of 0.46-m panchromatic and 1.84-m multispectral at nadir) and airborne imagery using kites usefully documented the development of Garamantian early urban trading communities during the late first millennium BC and early first millennium AD around oases and their productive hinterlands, which supported intensive agricultural zones...
(Mattingly & Sterry, 2013). However, spaceborne remote sensing relying on VHR commercial imagery has long been associated with high acquisition costs and the technical proficiency required for the application of advanced computational methods to high-resolution commercial satellite imagery (Davis & Douglass, 2020; Klehm & Gokee, 2020).

The exponential technological development witnessed during the 21st century has expanded the number of remote sensing platforms, with major technological corporations, such as Google and Microsoft, having been progressively increasing the resolution of their freely available imagery services, especially Google Earth and Bing Maps. The Endangered Archaeology of the Middle East and North Africa (EAMENA) project (https://eamena.org/) has developed a comprehensive image interpretation and recording based on the visual inspection of these open-access imagery portals. However, this imagery may not be suitable for the visual identification of archaeological features in specific geographical areas, due to the uneven coverage or visibility issues. Therefore, remote sensing methods ought to be adjusted to the environmental conditions of the selected study area and the specific research questions to be addressed. The widespread distribution and often clustered presence of still-standing drystone structural features in semi-arid upland environments has proven particularly conducive to remote sensing research, because they can be readily detected from VHR satellite imagery (e.g., Biagetti et al., 2017; Mattingly & Sterry, 2013; Rayne et al., 2017; Sadr & Rodier, 2012).

In the highlands of the Sahara and the northern Sahel, stone features were an important part of the architectural repertoire of Late Holocene communities (Amblard-Pison, 2006; di Lernia, 2013; MacDonald, 2015). They provide enduring evidence of human presence across this vast region, and their spatial distribution, predominantly on the edge of upland areas and along watercourses, offer insights into the seasonal mobility of pastoral communities in search of water and pastures (di Lernia, 2006). In semi-arid environments, these physical references would have offered visual landmarks in their mobility across the landscape and/or rooted sources of territorial identity. The presence of human skeletons within a range of excavated tumuli types from the central and southern Sahara confirms their role in mortuary rituals (Gauthier, 2015; Paris, 1996). In this paper, we document and analyse the monumental funerary landscapes along Dhar Tagant (a sandstone escarpment in south-eastern Mauritania), by analysing the morphometric properties and spatial distribution of ring tumuli, first reported in surveys by Ould-Khattar (1995).

Current legislation does not place constraints on remote sensing archaeological research making use of open-access imagery. For example, UN Resolution 41/65 (Principle XII) states that sensing other countries without their consent is legitimate as long as such states have been given access to data ‘on a non-discriminatory basis and on reasonable cost terms’ (Oduntan, 2019). Active space investments on a non-discriminatory basis and on reasonable cost terms (Principle XII) states that sensing other countries without their consent is legitimate as long as such states have been given access to data ‘on a non-discriminatory basis and on reasonable cost terms’ (Oduntan, 2019). Active space investments on a non-discriminatory basis and on reasonable cost terms (Principle XII) states that sensing other countries without their consent is legitimate as long as such states have been given access to data ‘on a non-discriminatory basis and on reasonable cost terms’ (Oduntan, 2019).
landscapes, particularly when we envision funerary monuments as places in which memory and meaning are created, ascribed and reimagined (Hirsch, 1995; Johannesson, 2012; Metcalf & Huntingdon, 1991; Van Dyke & Alcock, 2003). Funerary landscapes are also locales of life where social norms and identities are renegotiated and resources are obtained and exploited (Parker Pearson, 1993; Giraud & Cleuziou, 2009, p. 164).

The study of funerary landscapes and remote sensing are inextricably linked in the history of archaeology, starting with Crawford’s surveys and aerial photo identification of Britain’s Stonehenge Avenue and wider ritual landscape during the 1920s (Barber, 2016). The high degree of surface visibility in the semi-arid West African Sahel, characterized by high temperatures throughout the year and irregular annual rainfall of between 100 and 600 mm, is well suited for undertaking remote sensing surveys through an analysis of historical aerial photographs and satellite imagery. Correspondingly, aerial photography has been a staple of archaeological research in the region for the past 60 years. The study of Senegambian funerary landscapes saw the earliest use of aerial photography in African archaeology when Clos-Arceduc (1962) visualized the mounds at the Thiekène Mbacké monument complex, a large earthen tumuli field in the Djourbel region of Senegal (McIntosh & McIntosh, 1993; Pradines, 1996). Fieldwork on a tumulus at Thiekène Mbacké identified a pronounced geophysical anomaly that corresponded with seven inhumations and a bundle of iron artefacts inside the Kael 1 ring-ditch burial mound (Magnavita, 2017). Research in central and western Senegal had undoubtedly been encouraged by the discovery of a gold pectoral by Joire (1943) in Mound P at Nguiguélah, near the town of Rao, and the reports from Gard and Mauny (1961, p. 163) of other extant tumuli in the Lac de Guiers and Djourbel regions (Figure 1). At Santhiou Kohel, a tumulus inhumation was accompanied by a decapitated dog and a possible double human sacrifice, but, in contrast to Mound P, it seemed to lack grave goods (Gallay et al., 1982). The dense distribution of thousands of these earthen mounds across a large area of western Senegal (32,000 km²) suggests a highly ritualized, organized and labour-intensive process (McIntosh & McIntosh, 1993).

Remote sensing has also proven a suitable method in assisting archaeological fieldwork in Mali. The Centre International pour le Développement de l’Elevage en Afrique (CIPEA) identified 700 potential archaeological sites on aerial photographs, most of them in the Mema region of western Mali (Togola, 2008, p. 9). The aerial imagery was deposited in the Institut Géographique National in Bamako, and the relationship between putative sites, landforms and villages formed the structural basis for subsequent fieldwalking surveys in the flat landscapes of the region (Togola, 2008). Stereoscopic pairs of aerial photographs are useful for identifying mounds raising above the visually homogeneous floodplains of western Mali (MacDonald, 2017). Black-and-white historical aerial photographs can also provide glimpses into areas that were subsequently developed, although they can be unreliable for planning field surveys if land use has changed considerably (MacDonald, 2017).

Nowadays, the assessment of satellite imagery also comprises an integral part of current desk-based assessments aiming to identify suitable areas for conducting fieldwork in the West African Sahel.

| Site ID | Name                  |
|---------|-----------------------|
| 1       | Lake Pali (Mali)      |
| 2       | Timbuktu (Mali)       |
| 3       | Bandiagara Escarpment (Mali) |
| 4       | Tamani (Senegal)      |
| 5       | Flamenne Valley (Senegal) |
| 6       | Lac de Guiers (Senegal) |
| 7       | Djourbel (Senegal)    |
| 8       | Nguiquelah (Senegal)  |
| 9       | Sene-Ngaye (Senegal)  |
| 10      | Taskast wadi (Mauritania) |
| 11      | Tadrart Acacus (Libya) |
| 12      | Lake Turkana          |
| 13      | Lakiopia (Kenya)      |
| 14      | Cherangani Hills (Kenya) |
| 15      | Lower Omo Valley (Ethiopia) |
| 16      | Boreda (Ethiopia)     |
| 17      | Jalan (Oman)          |
| 18      | Aali (Bahrain)        |
| 19      | Homs (Syria)          |
| 20      | al-Ula (Saudi Arabia) |
| 21      | Draa Wadi (Morocco)   |
| 22      | Jabal Bouïa (Morocco) |

**FIGURE 1** Map showing the archaeological sites and geological features mentioned in the paper [Colour figure can be viewed at wileyonlinelibrary.com]
Two related surveys targeting the Azawad (Tombouze Project, around Timbuktu; Park, 2010, 2012) and the Lakes (Gorgor Valley, near Lake Fati; Coutros, 2017) regions of Mali made a similar use of ASTER and Landsat-8 medium-resolution satellite imagery to determine the coordinates of potential sites to be verified during their subsequent ground-testing fieldwork. The true colour of satellite imagery can make it easier to detect dark red brown patches that could represent laterite-tempered mud architectural features, such as the recently documented tumuli fields of the Pays Dô region of Mali (MacDonald et al., 2018). Dô and Kiri were two small Mande confederations (kafu), and their union was the ideological and political foundation for the development of the empire of Mali, a hierarchical and coercive state that was established during the thirteenth century (MacDonald et al., 2018). Conversations and observations with members of local communities, who prized large storage vessels within the mounds, led to the identification of numerous funerary tumuli built of clay covered by lateritic cobbles and gravel (MacDonald et al., 2018, p. 80).

Archaeological research in Mauritania has also made use of airborne remote sensing methods. Thomassey and Mauny (1951) deployed aerial imagery to complement their excavations at Koumbi Saleh (southern Mauritania) to document and interpret this site, which was part of the Medieval Ghana empire and was involved in trans-Saharan trade networks. Due to a paucity of archaeological excavations, Vernet (2017) recently made use of Google Earth satellite imagery to provide a more comprehensive account of the archaeological heritage of the Adrar region of central Mauritania, with a focus on linear stone-built features and enclosures. In the highlands of south-eastern Mauritania, the escarpments around Dhar Tichitt were sporadically visited by several French colonial researchers during the first half of the 20th century, who highlighted in their brief surveys the existence of large and well-preserved stone-masonry villages and funerary monuments (Laforgue, 1924, 1932; Laforgue & Mauny, 1939; Mauny, 1950, 1951; Verneau, 1920). The initial aerial survey and fieldwork results reported by Patrick Munson (1971) encouraged further research in the area, with subsequent researchers, such as Hugot at Akreijit (Holl, 1986), Amblard (1984, 1996) and Amblard-Pison (2006) at both Dhar Tichitt and Oualata, and two teams have conducted fieldwork in Dhar Néma (e.g., MacDonald et al., 2009; Person et al., 2006). At least one of these teams (MacDonald, personal communication) made extensive use of available historical imagery to inform fieldwork through the identification and characterization of sites belonging to the Tichitt Tradition (ca. 1900–400 BC), an early agropastoral economy based on intensive domestic pearl millet cultivation and livestock rearing (Amblard-Pison, 2006; Fuller et al., 2007; Holl, 1985; Munson, 1971). The Dhar Tichitt landscape exhibits a hierarchical settlement pattern (Holl, 1993), and the main Settlements were surrounded by high (approximately 2 m) and robust (approximately 1–1.5 m thick) stone walls with structured access gateways capped with lintel stones (MacDonald, 2020; Munson, 1971; Vernet, 1993).

The research by Park (2010) and Coutros (2017) in Mali also highlighted the centrality of south-eastern Mauritania for understanding settlement patterns and population movements in the Western Sahel during the first millennium BC and the first millennium AD: the pottery parallels (Faito facies) and the presence of stone enclosures on the highlands around Lake Fati illustrate a certain degree of relationship with the practices associated with the late Tichitt Tradition and the Bandiagara Escarpment (Coutros, 2017). In contrast, the earliest ceramics around Tombouze (Phase 1) highlight a greater affinity with the twine-impressed and sand-tempered assemblages of central Saharan proto-Berber groups (Park, 2010). The contact phase between these two main cultural groups in both south-eastern Mauritania and central Mali during the second half of the first millennium BC is correlated with the expansion of ironworking technology in the wider Western Sahel region. Within Mauritania, these patterns have been documented archaeologically through excavations conducted in the Dhar Néma region (MacDonald et al., 2009) and by fieldwork surveys in Dhar Tagant conducted by Ould-Khattar (1995). However, the publicly available level of documentation for the archaeological heritage of Dhar Tagant remains insufficiently detailed for assessing the spatial extent and architectural nature of sociocultural interactions during the second half of the first millennium BC and the first half of the first millennium AD. Therefore, we present here a preliminary characterization of the landscape distribution and morphometry of late prehistoric funerary tumuli in the Dhar Tagant region based on a comprehensive visual survey of freely available satellite imagery, which to our knowledge represents the first remote sensing publication aiming to analyse in depth the archaeological record of south-eastern Mauritania.

3 | AN ETHICAL ARCHAEOLOGICAL REMOTE SENSING FRAMEWORK FOR MAURITANIA

In Mauritania, the participation of externally funded researchers is often welcomed and actively encouraged by national authorities (MacDonald personal communication), although these local research needs cannot be easily addressed in the field due to security concerns: the UK’s Foreign, Commonwealth & Development Office, for example, has advised against all travel to a number of provinces in eastern Mauritania, including Tagant, for a number of years (https://www.gov.uk/foreign-travel-advice/mauritania). Undertaking remote sensing research into the prehistoric past of Mauritania is therefore a relevant way to address local research needs. Dr. Robert Bewley (EAMENA Director) and his advisor Pieter Tesch have acted as a liaison on behalf of the authors with Dr. Sidi Ould Salem, head of the Mauritanian Ministry of Culture, and his advisor (Dr. Camara) to request permission and inform about the research to be conducted in the region. These initial contacts and verbal research approvals followed preliminary remote sensing surveys aiming to probe the suitability of the imagery for archaeological research and heritage management and preceded the more detailed spatial analyses carried here.

The work conducted so far in the context of our research mainly relates to the Stage 1 of our framework (Figure 2), and a formalization of future collaboration between the University of Oxford and the
Mauritanian authorities is taking place. There are strong research incentives for an ethically informed remote sensing project to progress into Stage 2, involving a greater degree of personal and community engagement beyond ground truthing.

Endangered heritage monitoring: The multi-institutional EAMENA team has demonstrated the usefulness of integrating image interpretation, land-use mapping and traditional field survey to record, assess and analyse the preservation status of funerary landscapes in the Homs region of western Syria (Rayne et al., 2017, p. 20). The consensual and collaborative documentation of landscape modification through photogrammetry and satellite imagery archives of archaeological sites at risk of destruction by climate change or anthropogenic processes can lead to more active and effective institutional and external monitoring (Brooks et al., 2020; Campana, 2017; Khalaf & Insoll, 2019; Parcak et al., 2016; Rayne et al., 2020). These phenomena are likely to intensify in the face of increasing regional aridification, which also severely threatens the food security of agropastoral communities throughout the Sahel and beyond. High-resolution remote sensing datasets generated through remote sensing research in southern Mauritania will ideally form part of structured and integrated heritage inventories that can usefully inform subsequent archaeological fieldwork in the region and conservation policies to enhance the monitoring and safeguarding of sites, with knowledge transfers facilitated through outreach and local training workshops.

Institutional collaboration and capacity building: Certain aspects of collaborative research may be challenging when some countries lack specialized scholars, as could hinder local processes of knowledge generation and reception. The structural challenges and constraints that African social sciences researchers face are numerous, ranging from global structural frameworks that privileges certain forms of Africanist scholarship over local African voices (Hountondji, 2002; Mkandawire, 1993), a retrogressive and gerontocratic institutional hierarchy (Ake, 1994; Zeleza, 2003) and a systemic lack of funding opportunities, which leads to a lack of fair and accessible means for the generation and presentation of novel ideas by local scholars (Mama, 2007; Tettey & Puplampu, 2000). Ideology and religion may also explicitly dictate or implicitly shape national research priorities: for example, there is a lack of national scholars specializing in the pre-Islamic history and archaeology of Mauritania (Ould-Khattar, personal communication). Therefore, any externally led project ought to consider how its methods and research outputs will contribute to improving the

![FIGURE 2](image-url) Our proposed multi-stage ethical framework to inform and structure archaeological remote sensing in Mauritania
situation or otherwise. In Mauritania, outreach lectures and training workshops at the University of Nouakchott could prove inspirational for young scholars (Ould-Khattar, personal communication).

Ethical remote sensing and local community engagement: The use of geospatial technologies should not be conceptualized as inherently incompatible with ‘on-the-ground’ collaboration with participant local communities (Klehm & Gokee, 2020, p. 4); ethical research ought to avoid alienating local communities from the heritage in the landscapes that they inhabit should they wish to engage and participate in the process. East Africa has witnessed several particularly successful examples on how remote sensing and the archaeology of living communities in Africa can go hand in hand. Arthur et al. (2020) collaboratively mapped recent settlement histories in southern Ethiopia with Boreda elders, jointly charting architectural features, physical settings and the oral histories associated with sacred groves and other features in the landscape. Abandoned fortifications in particular hint at conflict and resistance versus neighbouring slave raiders and the (northern) Ethiopian state (Arthur et al., 2020). This approach highlights and documents the multifaceted nature of human landscape use. As shown by Lunn-Rockliffe (2018) working alongside the Sengwer community of the Embobut Forest (Cheranagi Hills, Kenya), collaborative research has considerable implications for empowering local communities amidst attempts to uproot and displace them, through the documentation of the deep histories of community presence within the land.

These processes of community engagement are not always straightforward, however; the experiences of widespread population genetic sampling suggest that some of the complexities of research may hinder the communities’ comprehension of the disclosed information and the actual purpose of the investigation, which in turn may compromise the degree to which consent was sufficiently informed (MacEachern, 2013; Nyika, 2009). It is the ethical responsibility of researchers to communicate in a clear and easy to understand way to prevent such issues from arising, perhaps by inviting a locally trusted translator to mediate in the conversation and keeping records of interview transcripts—and ideally a summary of research outputs—in relevant local languages for future consultation (cf. Rearden & Fienup-Riordan, 2013). Furthermore, geopolitical and public health issues may prevent on-the-ground collaboration with local communities. Fostering grassroots collaboration schemes with local communities through web applications can help towards the co-identification, mapping and characterization of archaeological features visible in the satellite imagery (cf. Harris, 2012). At the same time, the applicability of community engagement approaches and crowd-source mapping mechanisms in these contexts remains relatively untested, particularly in the absence of on-the-ground data quality validation mechanisms due to fieldwork restrictions.

Moreover, communities who may claim an ancestral connection with a particular heritage have occasionally been territorially displaced and/or experience sociopolitical marginalization, and ‘recently’ arrived local communities may have very little emotional or cultural connections with the prehistoric heritage that coexist in the landscape. For example, Kennedy (2011) described how the Bedouin communities of the Eastern Desert of Jordan and Saudi Arabia refer to the seasonal hunting camps and funerary sites that he had surveyed in the desert using satellite imagery as ‘the works of old men’. Similarly, Ould-Khattar (1995) relates how nomadic Berber pastoralists in the Tagant (Mauritania) did not identify with the original builders of archaeological sites in the region, despite camping near the sites and occasionally making use of some of the stone structures.

Water points and paths are relevant components of agropastoral communities in arid landscapes (Biagetti et al., 2012), and Ould-Khattar (1995, p. 56) mentions the familiarity of local nomads that visit Dhar Tagant with local freshwater sources, such as perennial springs and seasonal watercourses. At the same time, the depth of landscape and cultural knowledge of local communities may fluctuate from one generation to the next, as stressed by Biagetti et al. (2012) for the Kel Tadrart Tuareg living in the Acacus mountains, whose ability to read Tifinagh inscriptions is quickly fading, and steep and narrow passageways are losing their historical primacy since the advent of four-wheeled vehicles in the region (Biagetti et al., 2012). Thus, even in the absence of cultural continuity, mapping subsistence routes and landmarks in detail would undoubtedly help us illustrate potential relevant hotspots for prehistoric settlement and mobility, as well as help record the seasonal lifeways and landscape interactions of contemporary nomadic groups.

4 | METHODOLOGY

4.1 | Best practices in remote sensing recording

The ever-growing body of data collected through spaceborne and airborne remote sensing requires researchers to ensure that they follow best practices in the systematic examination, processing, description, analysis and interpretation of available information. When undertaking a visual remote sensing survey using freely available satellite imagery, the extent of the survey ought to be accurately mapped, ideally alongside landmarks such as topography, hydrography and settlements, followed by a comprehensive report documenting the location and description of identified sites. A minimal site documentation should include a coordinate reading at its approximate centre, size in hectares, a picture depicting the site visually and a brief site description of visible surface features and its surroundings (MacDonald, 2017; Wilson, 1982, p. 195). The process of feature recording from spaceborne imagery is not always straightforward, given how atmospheric conditions at the time of data capture might affect the clarity and visibility of the imagery. The combination of multiple imagery sources that account for annual or seasonal variation can help overcome this potential limitation, while also providing an initial validation stage that is particularly relevant when ground survey data are not yet available, as suggested by Rayne et al. (2017). Unfortunately, the GSD of Google Maps and Google Earth satellite imagery for our Dhar Tagant survey area was rather coarse, which prevented cross-platform identification of individual features readily visible on the Bing Maps imagery.
During the early stages of remote sensing research in an under-explored region, several authors have highlighted the importance of developing a general and standardized morphological classification, arranged on hierarchical principles and anchored in quantitative ranges (Kennedy & Bewley, 2004, 2009; Kennedy & Bishop, 2011; Wilson, 1982). For these reasons, we undertook a comprehensive morphometric characterization of funerary tumuli in the Dhar Tagant region, complementing preliminary qualitative typological assessments outlined by Ould-Khattar (1995). When researchers commission or directly acquire satellite imagery, pattern recognition algorithms (e.g., Davis, 2019) can semi-automatically digitize archaeological deposits with suitable spatial and morphological accuracy. To apply such automated procedures on the freely accessible imagery hosted on web-mapping portals used here (i.e., Bing) requires special licensing. As such, for our analyses here, we computed detailed and metrically accurate transcription of feature data on GIS after manually recording and digitizing the sites.

4.2 | Analytical methods employed

ArcGIS Pro 2.7, a geographical information system (GIS) software package, was employed to manipulate satellite imagery and carry out spatial analyses using in-built geoprocessing tools. Bing Maps was loaded into the GIS as a basemap after obtaining a license key from Microsoft. Metadata for Bing Maps imagery is not readily available; however, most of our study area seems to have orthorectified VHR imagery of 30–50 cm (i.e., already corrected for distortions derived from terrain morphology and viewing angle), making it ideal for visual inspection and analysis.

Based on this freely available satellite imagery service, we undertook a preliminary survey of Dhar Tagant (south-eastern Mauritania). Dhar Tagant is an escarpment complex located south of the town of Tidjikjila and west of Dhar Tichitt (Figure 3). These dhars represent a topographical transition encompassing flat upland areas on the edge of the Tagant Plateau, slopes of varying steepness intersected by shallow wadis and narrow canyons (dakhlat) and interdunal alluvial low-lands (baten) that mark the start of the Aoukar Depression (Holl, 2009; Munson, 1971).

Dhar Tagant was surveyed archaeologically by a Franco-Mauritanian team in the late 1980s, collecting information on over 200 sites (Ould-Khattar, 1995). Nonetheless, intrasite maps (with a few notable exceptions authored by Robert Vernet) or site distribution maps have not been publicly reported, due to concerns regarding their future integrity due to tourist and local nomadic groups visiting and potentially looting them. Indeed, Challis et al. (2005, p. 460)

![FIGURE 3 Map of south-eastern Mauritania with the archaeological sites and geological features mentioned in the text [Colour figure can be viewed at wileyonlinelibrary.com]](image-url)
mention, for example, that it was not unusual for locals to take grindstones and pottery away from sites in the Guilemsi Ridge (north of Tidjikja, Tagant Plateau). This situation has hampered any subsequent attempt at understanding the Dhar Tagant archaeological record up to this day, and the material heritage of the region remains insufficiently documented, in contrast with Dhar Tichitt and other areas of the West African Sahel, despite similar underlying issues.

4.2.1 | Clustering analysis

In our preliminary survey, every apparent settlement was digitized with a point feature in the approximate centre of the site, assigned into clusters with the Density-based Clustering tool. The ‘self-adjusting’ (HDBSCAN) algorithm (Campello et al., 2013) was used to automatically group sites into clusters based on cluster probability or stability.

4.2.2 | Multivariate morphometric analysis

The funerary monuments in Dhar Tagant were analysed according to their size, shape and distribution. Apparent tumuli were visually identified and then digitized as point features placed in the centre of the monument. Three metrics were measured:

- **Size**: The outline of the tumuli and, where present, their enclosing outer ring were digitized manually as two separate polygon layers. In order to automatically obtain an approximation of the diameter of these circular tumuli, the Minimum Bounding Geometry tool was carried out on both polygon layers to generate a circle of best-fit around each feature—the tool was also able to report the diameter of the circles. The two layers were then merged with the Spatial Join tool and then exported as a table for further statistical analysis.

- **Circular symmetry (roundness)**: The actual outlines of the tumuli (and their outer rings, where present) were compared with their perfectly circular, ‘idealized’ versions generated above, as a measure of roundness. The area of the features was divided by that of their circular versions to obtain an index measuring symmetry with values ranging from 0 to 1, where higher values indicate that a feature is more circular.

- **Deviation of tumuli alignment from geometric centre of monument**: For tumuli possessing an outer ring, the extent of tumuli deviation from the geometric centre of the ring monument was measured. The ‘Feature to Point’ tool was used to generate a point at the geometric centre of both the tumuli and the outer ring. A geoprocessing model was then created to automatically generate the iteration of polylines between these two points using the Points to Line tool. The length of this line was noted and used in the statistical analysis.

A table of ring tumuli and the morphometric values generated above were subjected to multivariate statistical analyses in R (version 3.5.1: R Core Team, 2018), a free software environment for statistical computing and graphics. To select the most suitable variables and prevent the simultaneous use of highly correlated ones, we performed the Kaiser–Meyer–Olkin (KMO) factor adequacy test (0.6 cut-off value) and assessed with the Bartlett test whether the resulting correlation matrix was an identity matrix (i.e., one where all residual correlations are zero), both using the psych library (Revelle, 2018). To reduce the dimensionality of the dataset while retaining the original distances between the morphometric data from monument clusters, we undertook a principal component analysis (PCA) using the FactoMineR library (Le et al., 2008). The PCA graph was generated using the library ggfortify (Horkosh & Tang, 2018) with the ‘Dark2’ Brewer palette. To test the significance of the PCA variables, we employed the Mardia multivariate normality test using the MVN library (Korkmaz et al., 2014) followed by a robust pairwise permutation MANOVA (999 permutations) using the library RVAideMemoire (Hervé, 2019). A similar methodological workflow is used in geometric morphometric analyses to test for multivariate statistical significance in non-parametric distributions (e.g., Linares-Matás et al., 2019; López-Cisneros et al., 2019; Yravedra et al., 2019).

**Workflow**: An automated geoprocessing workflow is available as an ArcPy script, and the R code for the multivariate morphometric analysis is also accessible from the link in the Data Availability Statement.

4.2.3 | Viewshed analysis

Cumulative reflective viewshed analysis was used to infer visual relationships between a sizable group of 137 funerary monuments and their immediate landscape, where the Taskast wadi meets the Dhar Tagant escarpment. Using a publicly available 30-m Digital Elevation Model (DEM) of Mauritania (Lee, 2013) as a surface, we calculated which parts of the landscape the monuments were visible from, assuming the height of individual observers in the landscape was 1.75 m tall (a standard human [male] height, cf. Gillings & Wheatley, 2001), and the monuments no taller than 2 m (after Ould-Khattar, 1995). The Density-based Clustering tool was once again used to assign each monument to a cluster, based on their proximity. This time, a ‘defined-distance’ (DBSCAN) algorithm was used (Ester et al., 1996), with a minimum of two features per cluster and a search distance of 300 m—six clusters were identified in this manner. The reflective cumulative viewshed was carried out on all 137 monuments as a group. Reflective viewsheds were also generated for each individual monument cluster.

5 | RESULTS

5.1 | Settlement patterns in the Dhar Tagant region of south-eastern Mauritania

Our preliminary survey of the Dhar Tagant using freely available satellite imagery noted that prehistoric sites can be found throughout the escarpment, albeit in clusters of variable extent and density (Figure 4). Our survey confirmed the general pattern documented for Tichitt...
Tradition drystone sites, which predominantly comprise a series of enclosed household compounds forming larger aggregated spatial units on the flat plateau and escarpment slopes (MacDonald, 2015).

On the basis of size and complexity, we have tentatively identified the following settlement types:

**Type 1: Simple enclosures**

These are small, isolated enclosures. They could potentially represent cattle kraals and are found throughout the study area. Some of these structures may have been reused or constructed anew in the recent past by local nomadic pastoralists.

**Type 2: Sites with multiple enclosures**

These are small, isolated and asymmetrical collections of around 3–15 enclosures, occasionally joined together. They are mostly found on slopes, without enclosing walls. In some instances, however, they are located in relatively inaccessible and include defensible areas with partial fortifications.

**Type 3: Large complexes**

These are large conglomerations of enclosures in an organic, disorganized pattern. There are two main variants: those found on the slopes of the escarpment and those built on the flat plateau that overlooks them, such as the early ironworking community of T150 (dated ca. 150 BC–AD 50; MacDonald, 2020; Ould-Khattar, 1995; Figure 5). Sites on slopes are often less nucleated and do not exhibit outer fortifications, whereas those atop the escarpments normally feature boundary walls. The largest walled settlement encompasses approximately 35 ha. Within the established Tichitt-Oualata sequence, the Late Tichitt phase (ca. 1000–400 BC) witnessed the increasing development of defensible settlements at the top of the escarpment, notionally due to conflict between Tichitt Tradition populations and incoming Berber groups (MacDonald, 2020). The dates provided by Ould-Khattar (1995) suggest that the bulk of occupation in the Tagant was during or after this Late Tichitt period, with 12 of a total of 15 14C calibrated determinations falling between 800 cal. BC and cal. AD 500, which is consistent with the presence of ironworking at most of the stonewalled settlements on the plateau edge (Ould-Khattar, 1995, p. 175).

**Type 4: Grid complex**

Finally, we have documented a unique site complex in the region, with potential streets as part of a well-structured layout style (Figure 6). A series of regular circular features are evenly distributed within rectangular enclosures. Their functionality and significance are still unknown, but, given their morphological divergence from Tichitt Tradition domestic enclosures, we do not rule out a potential role in funerary practices. Two wadis that converge on the base of the slope separate the different components of this agglomeration. The presence within a 2-km radius of several agricultural terrace complexes on the escarpment slope may hint at some degree of agricultural intensification.

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**Figure 4** Distribution of settlement clusters along Dhar Tagant [Colour figure can be viewed at wileyonlinelibrary.com]
Tichitt Tradition funerary cairns have been identified along the central Dhar Tichitt escarpment, particularly in the vicinity of Dakhlet el Atrouss (Amblard-Pison, 2006). Cairns are stone monuments visible on satellite imagery as small circular or oval features, sometimes associated with ring enclosures of varying size, although ring tumuli are not particularly common in Dhar Tichitt. Beyond the Dhar Tichitt clusters, funerary monuments do not seem particularly common along other south-eastern Mauritanian escarpments, such as...
Dhar Oualata and Dhar Néma (MacDonald, 2015; MacDonald et al., 2009).

To improve our understanding regarding the nature of the monumental funerary landscapes of south-eastern Mauritania, we conducted a preliminary remote sensing survey along the Dhar Tagant escarpment (approximately 235 km). The existence of at least two categories of funerary monuments in Dhar Tagant, with some degree of internal morphological variability, is suggested in survey accounts of the region (Ould-Khattar, 1995, pp. 432–437; Figure 6).

Descriptions of conical funerary monuments in the region commonly highlight the existence of a stone ring (Ould-Khattar, 1995, p. 69). Using the ring tumuli described by Ould-Khattar (1995) as an initial diagnostic feature (Figure 7), we have identified a total of 183 ring tumuli so far, which increases to 276 potential stone funerary monuments when we include tumuli-like stone features lacking an outer ring.

These features differ in size and shape from suggested funerary monuments in the western Adrar region of Mauritania, which tend to comprise low-level heaps of stones and a rectangular plan (Gauthier, 2015), as well as potential rectangular funerary features found in association with rock art at the Guilemsi Ridge in the Tagant, approximately 50 km north of Tidjikja (Challis et al., 2005).

The spatial distribution of funerary monuments in the region was unreported in distribution maps, although Ould-Khattar (1995) mentioned the existence of at least one major cluster around site T172 (the precise location of which remains undetermined): C'est dans la zone située au Nord de ce monument et les hauteurs voisines que se situe la majorité des monuments funéraires, nous en avons décompté une cinquantaine sans avoir été exhaustif. (Ould-Khattar, 1995, p. 124) [Translation by the author: Most funerary monuments were found in the area located to the North of this monument and the neighbouring uplands, numbering around fifty without this being comprehensive.].

Indeed, the local densities and degree of clustering of the Dhar Tagant monuments are noteworthy (Figures 8–10).

To ascertain quantitatively the typological nature of ring mound funerary monuments, we undertook multivariate statistical analyses. Based on the KMO factor adequacy test values (overall value = 0.74), we selected the following variables: inner tumulus diameter (0.69), ring diameter (0.68), ring circular symmetry (0.82) and deviation of central feature alignment (0.83). Bartlett's correlation matrix test yielded a statistically significant result (p value = 1.216404e-44), demonstrating that the resulting dataset was conducive for our research purposes.

The Mardia multivariate normality test confirmed that the PCA values had a non-normal distribution, and therefore, we tested significance through a robust pairwise permutation MANOVA (Table 1). This test confirmed that the composition of Clusters 9 and 14 were significantly different from all other spatial clusters.

The differences between these funerary monument clusters are visually represented through a PCA (Figure 11). The results can be interpreted through a combination of the PCA factor map and visual examination of satellite imagery.

The funerary monuments of Cluster 9 are generally more elongated and asymmetrical and are located on a slope above a relatively large drystone settlement (Figure 12), whereas the funerary monuments of Cluster 14, at the entrance of the Taskast wadi, are smaller and more symmetrical. In our view, the funerary monuments of Cluster 9 do not readily fit either type described by Ould-Khattar (1995), whereas those from Cluster 14 do perhaps fit well with Ould-Khattar's monument type on the right side of Figure 7, although a definite attribution would require ground verification. Given the lack of regional parallels for comparative contextualization, without ground verification and systematic dating, it is difficult to interpret whether the unusual morphometric nature of Cluster 9

![Figure 7](image-url)  
**Figure 7** Two types of prehistoric funerary monuments in the Dhar Tagant region of south-eastern Mauritania (vectorized after Ould-Khattar, 1995, fig. 35)
**FIGURE 8** Distribution of funerary monument clusters along the Dhar Tagant region [Colour figure can be viewed at wileyonlinelibrary.com]

**FIGURE 9** Satellite view of several ring tumuli from Cluster 1, at the entrance of the Taskast wadi (Dhar Tagant) [Colour figure can be viewed at wileyonlinelibrary.com]
monuments is a result of their chronology, specific cultural considerations or their topographic location.

The highest concentration of funerary monuments (49.6%, \(n = 135\)) can be found within 15 km² near the origin of the Taskast wadi. The Taskast wadi (Oued Taskast) defines an important part of the boundary between the regions of Assaba and Hodh el Garbi, and it still is the main axis of mobility across the Hodh basin (see Figure 3). We have selected this place as our focus area for undertaking detailed visibility analysis (Figure 13), based on its historical significance for human mobility across the landscape and the degree of monument clustering documented. Our cluster-based and cumulative reflective viewsheds (Figures 14 and 15) indicates that people approaching the entrance of the wadi along the base of the escarpment slopes would have seen these funerary monuments, and the central clusters (2–5)

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**TABLE 1** Pairwise comparisons of principal component analysis (PCA) coordinate data by funerary monument cluster using permutation MANOVAs (test: Wilks, 999 permutations)

| Cluster ID | 1    | 4    | 5    | 8    | 9    | 13   |
|------------|------|------|------|------|------|------|
| 4          | 0.966|      |      |      |      |      |
| 5          | 0.091| 0.215|      |      |      |      |
| 8          | 0.035| 0.316| 0.032|      |      |      |
| 9          | 0.001| 0.001| 0.001| 0.001|      |      |
| 13         | 0.007| 0.305| 0.378| 0.388| 0.001|      |
| 14         | 0.005| 0.002| 0.002| 0.001| 0.001| 0.023|

Note: Statistically significant \(p\) values (<0.05) are in bold.

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**FIGURE 11** Principal component analysis for funerary monument clusters in Dhar Tagant. PC1 and PC2 (shown here) explain 82.88% of the variance in the dataset. The legend numbers represent our Cluster ID assignation. Cluster 1 stands as representative of all those which were not statistically different from it, as a way to simplify the graph [Colour figure can be viewed at wileyonlinelibrary.com]
FIGURE 12  Cluster 9 funerary monuments in their landscape context. Note their position on the slope above a sizeable settlement (7.7 ha) that morphologically resembles those of the Tichitt Tradition [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 13  Satellite imagery showing our viewshed analysis area in the Upper Taskast wadi (Dhar Tagant) [Colour figure can be viewed at wileyonlinelibrary.com]
FIGURE 14  Mosaic of reflective viewshed analyses for the different funerary monument clusters at the entrance of the Taskast wadi [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 15  Cumulative reflective viewshed of the totality of funerary monuments at the entrance of the Taskast wadi. On the left: local satellite imagery for visual reference; on the right: cumulative reflective viewshed on a hillshade DEM visualization. For an association between ID keys (a–f) and cluster number, see Figure 14 [Colour figure can be viewed at wileyonlinelibrary.com]
would have been visible also as people approached the escarpments from the wadi itself. The relevance of visibility and topography in the constitution and significance of funerary monuments in the wider MENA region is most prominently illustrated by the hundreds of Nabatean rock-cut tombs found in the hinterland of Petra, Jordan (Wadeson, 2012). At the same time, it is also worth noting that no single spot in the Taskast landscape was able to visualize all 135 funerary monuments. Interestingly, due to the rugged topography of the slope created by intersecting wadis, none of the funerary clusters exhibit any degree of intervisibility, which means that they are not visible from one another. Although the relevance of the monuments themselves seems clear, it is however unknown whether any of these individual monument clusters, determined through spatial statistics, held any particular sociocultural significance. In settlement contexts, exclusionary nonmutual viewsheds have previously been used to suggest political autonomy or territoriality (Lambert, 2002; Lock & Harris, 1996), and we aim to explore this sociopolitical dimension further in subsequent studies of Late Holocene settlement patterns and funerary landscapes in southern Mauritania.

6 DISCUSSION: REMOTE SENSING, MONUMENTAL FUNERARY LANDSCAPES AND SOCIAL ORGANIZATION IN SEMI-ARID ENVIRONMENTS

The interdependent relationship between the physical configuration and asymmetries in the social constitution of places is a central dimension in contemporary African archaeology (Klehm & Gokee, 2020; Wynne-Jones & Fleisher, 2015), and remote sensing can decisively contribute to this discussion through the large-scale study of settlement patterns and monumental funerary landscapes. The use of remote sensing for the study of monumental funerary landscapes in semi-arid landscapes is indeed growing in popularity, because technological advances are enabling detailed spatial analyses at unprecedented rates and scales: a recent paper details the application of computational machine learning methods automatic delineation of Khirgisuur stone burial monuments in Mongolia (Monna et al., 2020), whereas an ongoing project combining light aircraft remote sensing and fieldwork aims to document the Bronze Age and Nabatean funerary landscapes around the Al Ula wadi of northern Saudi Arabia (Smith, 2019).

Large clusters of funerary monuments developing over considerable time periods represent permanent and deeply rooted ancestral claims to the land. At the same time, funerary landscapes are particularly active spatial and conceptual locales of social interaction in the negotiation and establishment of cultural identities, along a multiscalar axis of centrality and liminality (Ashmore & Knapp, 1999; Di Paola, 2018; Holm et al., 2009). In south-eastern Mauritania, the nucleation of funerary monuments around Dakhlet el Atrouss has been invoked to stress the sociopolitical and ideological centrality of this site within wider regional settlement hierarchies during the second millennium BC (Holl, 1993; MacDonald, 2015). Most funerary features around this Tichitt Tradition megasite are cairns, a conspicuous element of Levantine and North African prehistory (Bradbury, 2011; Gatto et al., 2019; Gauthier, 2015), with the two largest features being located within two large enclosures that form part of the settlement layout, whereas most are found on the flat plateau to the north of the site and the surrounding escarpment slopes. The largest prehistoric settlement identified in Dhar Tagant (approximately 30 ha) also features a single ring tumulus feature within the walled area (Ould-Khattar, 1995), and another one in the immediate vicinity. In Morocco, south of the Atlas Range, the pre-Islamic site of Jabal Bouia is also considered a central place, with the settlement overlooking a large necropolis and the surrounding plain (Bokbot, 2019; Margat & Camus, 1959). In a similar fashion, albeit at a considerably larger scale, the monumental funerary landscapes of Bahrain during the Early Dilmun I-II period (ca. 2200–1800 BC), studied through extensive aerial surveys and large-scale excavations, show increasing nucleation around the royal cemetery of A’ali, mirroring processes of sedentarization, vertical hierarchization and centralization taking place in settlements for the living (Håjlund, 2007; Håjlund et al., 2008; Kveiborg, 2007; Laursen & Johansen, 2007; Laursen, 2008; Magee, 2014, p. 164).

Nonetheless, the monument clusters around the Taskast wadi examined through satellite imagery do not exhibit a close spatial association with medium or large settlements (>3 ha). A lack of association between spaces of the living and funerary landscapes has also been documented for the tumuli fields in Pays Dô, interpreted as persistent focal points in the sacred landscape of the 12 Dô villages, integrated ideologically through ritual practices associated with an interconnected network of shrines (MacDonald et al., 2018). Similarly, the Senegambian tumuli fields along the River Gambia (Sine Ngayène, Wanar, Wassu and Kerbatch), encompassing over 1500 years of human funerary practices and statecraft practices, lack associated settlements despite comprehensive ground surveys (Bocoum, 2000; Gallay et al., 1982; Laporte et al., 2012). The investment of wealth and labour involved in the construction of large earthen mounds and megalithic monuments is considerable, as these sites contain over a thousand funerary monuments, combining earthen mounds and almost a hundred stone circles made of carefully worked laterite pillars (Gallay, 2006; Holl et al., 2007; Laporte et al., 2012; Ozanne, 1965; Thilmans et al., 1980). This pattern indicates a degree of social stratification in the wider Senegambia region, whose geographical positioning may have allowed these agricultural communities to control the flows of valuable mineral resources, such as iron and gold (Posnansky, 1973, 1982). These extensive monumental funerary landscapes appear to have acted as catalysts of identity and belonging by virtue of their cosmological centrality in their respective socio-economic systems.

At the same time, societies with a strong pastoral component experience seasonal patterns of mobility in search of fresh water and greener pastures, often moving between highland and lowland areas. The earliest occupations of the basalt flow landscapes of the Orontes basin of western Syria by seasonal herding communities are tentatively associated with the arrival of domesticated donkeys to the region during the Chalcolithic and the early Bronze Age (Philip &
Brady, 2010, p. 160). The study of satellite remote sensing data spanning over 50 years (Corona KH-4-B and KH-7, as well as panchromatic and multispectral Ikonos imagery) and historic aerial photographs led to the identification of hundreds of thousands of potential cairns on the uplands (Bradbury, 2011; Bradbury & Philip, 2011). The passageways that channel these movements tend to act as liminal places, spatial and sometimes contested thresholds between different territories and topographies (Van Gennep, 1909). A particularly dramatic example is Foum Larjam, an extensive protohistoric tumuli field on the Jabal Ben Selmane mountains, extending along the Draa Wadi in central Morocco (Bokbot, 2019; Mattingly et al., 2017).

The Late Pastoral communities (3900–1700 cal. BC) of the Tadrart Acacus region of the central Sahara erected large conical tumuli visible from considerable distances, near passageways, hilltops or steep slopes—rather than on adjacent lowland areas and often away from settlements (di Lernia, 2013). These visual cues marked the existence of ‘places to be remembered’ (di Lernia, 2006, 2013; di Lernia & Tafuri, 2013), and they may have assisted small livestock transhumance between ephemeral summer camps in the lowlands and specialized winter settlements in upland areas, which offered seasonal refugia under increasingly arid conditions (Cremaschi & di Lernia, 1999; di Lernia, 2006, 2013; Holl, 1998). The largest funerary feature in the Tadrart Acacus landscape is an undated ‘keyhole monument’ (35 m in diameter) involving a central tumulus and a complex arrangement of enclosing oval rings (di Lernia, 2013, p. 184). Located on a high terrace, it marks the starting point of an important wadi (di Lernia, 2013, p. 184). The spatial context of this monument resembles that of the dense monument clusters documented around the start of the Taskast wadi in Dhar Tagant, which are also visible from adjacent lowland areas, as shown above.

The Taskast wadi represents a reliable route of interaction between the highlands of the Tagant Plateau and the southern Mauritania lowlands that nomadic camel pastoralists still follow to this day (Ould-Khattar, 1995). The bulk of the prehistoric occupation of Dhar Tagant has been linked with processes of aridification during the first millennium BC in the Tichitt-Oualata region (MacDonald, 2015, 2020; Ould-Khattar, 1995), and it is plausible that Late and Terminal Tichitt communities in the Tagant mirrored Late Pastoral groups in their reliance on small livestock over cattle, with greater mobility demands but lower water requirements; nonetheless, further fieldwork involving zooarchaeological research is still needed to confirm the subsistence base of late prehistoric communities in Dhar Tagant. The centrality of the Taskast valley in regional mobility patterns is further evidenced by long-distance connections between the western Sahel and the Islamic communities of northwest Africa through the medieval entrepòt of Tegdaoust, located deep in the Hodh basin (Levtzion, 1985; Mauny, 1961; McDougall, 1985; Robert, 1970). Preliminary visual survey of satellite imagery in the highland areas around Tegdaoust has also revealed the presence of several ring tumuli and standalone conical cairns resembling those at the Dhar Tagant entrance of the Taskast wadi, which further strengthen the degree of socio-economic connectivity and cultural significance of this geographical features to prehistoric and Medieval communities.

The presence of a stone ring around the main body of the cairn, an additional layer of elaboration that enhances the visual appearance of the monument, is a common feature of Dhar Tagant funerary monuments. Similarly, it seems to be a recurrent pattern among Lybico-Berber communities in the central and western Sahara (Gauthier, 2011) and in East Africa, where the relationship between the construction of drystone architectural features and the emergence and spread of pastoralism is particularly strong (Davies, 2013; Hildebrand & Grillo, 2012; Mack & Robertshaw, 1982; Marshall et al., 1984; Wendorf, 1998). At Lokori (south-western Turkana), 167 funerary structures consisting of a central cairn with a ring of standing stones have been documented; the excavated examples show that they cover a burial pit hosting a single individual of varying age and sex but in all cases without associated grave goods (Davies, 2013; Lynch & Robbins, 1978, 1979; Soper & Lynch, 1977). The Laikipia cairns (central Kenya) also seem to have experienced a certain degree of spatial regularity in their distribution, which perhaps indicates some degree of trail marking in addition to their relevance for place making and remembrance of the dead (Lane et al., 2007). The spatio-temporal patterning of pastoral sites and stone-built features appears to indicate novel forms of material engagement with the landscape, as notions such as mobility, memory and territoriality were redefined. With regard to the Dhar Tagant landscape, it appears that the Late and Terminal Tichitt phases involved some degree of political decentralization in comparison with the socio-economic hierarchies documented for the Classic Tichitt in Dhar Tichitt-Oualata (Holl, 1993; MacDonald, 2020; Munson, 1971). The considerable clustering of funerary monuments at the entrance of the Taskast wadi, a liminal location in relation to the main walled settlements in Dhar Tagant, appears to hint at higher seasonal mobility requirements by the communities of the late first millennium BC and the early first millennium AD in the region.

Future collaborative engagement with local communities in southern Mauritania may offer ways to better understand and complement interpretations of the ecogeographical significance of the distribution patterns of settlements, rock art locales and/or visually prominent funerary monuments, even in the absence of cultural continuity. For example, the Joint Hadd Project in eastern Jalan (Oman) has highlighted the depth of the vernacular geographical knowledge of local Bedouin collaborators and how the representation of space delineated through the distribution of Early Bronze Age collective burials in the region resembles the distribution visual cues that nomadic Bedouins use to orientate themselves as they move through this arid region (Giraud & Cleuziou, 2009). Indeed, integrating remote sensing approaches with local landscape knowledge networks is proving a very successful approach across a wide range of environments (e.g., Davis et al., 2020; Lim et al., in press) and is well on its way to become a standard ethical practice in archaeology.

**7 | CONCLUSIONS**

Monumental funerary landscapes are palimpsests of memory. In the West African Sahel and beyond, they represent a commemoration of
belonging, identity and authority through reference to ancestors, while simultaneously comprising a range of conspicuous visual cues that guide the lives and movements of the living. In semi-arid environments, these material manifestations of mortuary practices contributed to the creation of place, shaping the roots of identity among sedentary agricultural societies and providing visual cues to assist and channel the movements of seminomadic pastoralist groups through the landscape. In Dhar Tagant (south-eastern Mauritania), funerary monuments are usually located on visually prominent areas, often along communication routes, but unlike the isolated monuments in the Tadrart Acacus, they also exhibit a high degree of clustering—particularly near the entrance of the Taskast wadi. Their liminal position, at the entrance of this interregional pathway but separated from the main walled settlements in the area, is in stark contrast with the pattern documented around Dakhlet el Atrouss. These differences may be potentially suggesting more decentralized and more actively negotiated socio-economic and political landscapes during the Late Tichitt phase in the Dhar Tagant. Forthcoming research into the nature and distribution of settlement sites in the region will elucidate further the significance of the patterns of land use and memorialization reflected by the funerary monuments in the region.

Our research is part of consolidated and emerging projects aiming to monitor endangered heritage at a pan-regional scale, particularly in areas of limited accessibility on the ground, with an explicit focus on regional training to facilitate the research initiatives of local archaeologists and international collaborations (Fisher et al., 2021; Rayne et al., 2017). Postcolonial archaeological research should be proactive and decentralizing, starting by exploring the implications and purposes of what we do, and the way we do it, taking into account whose heritage is being interpreted. Ethical remote sensing research ought to promote the collaborative use of accessible datasets that maximize cross-platform portability and knowledge sharing, as it will provide invaluable assistance towards informing heritage protection and planning policies. Remote sensing research could therefore be seen as an opportunity to contribute responsibly to the development of more nuanced versions of the African past, in ways that highlight the innovativeness and resilience of local resource management strategies in the context of climate change, challenging entrenched and overtly negative stereotypes about the African past, present and future (Giblin et al., 2014; Smith, 2014).

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CONFLICT OF INTEREST
The authors declare that they have no known competing financial interests that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT
The ArcPy and R Scripts for Processing Tumuli Geometric Data in Mauritania, which we applied to Dhar Tagant funerary monuments in the present paper is openly accessible from the Oxford Research Archive (ORA): https://doi.org/10.5287/bodleianexK1YngGB.

ORCID
Gonzalo J. Linares Matás https://orcid.org/0000-0002-0429-7636
Jonathan S. Lim https://orcid.org/0000-0001-9321-7695

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