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SPATIAL DISTRIBUTION OF ARCHAEOLOGICAL SITES IN LORALAI DISTRICT, BALOCHISTAN, PAKISTAN BASED ON GEOGRAPHIC INFORMATION SYSTEM (GIS)

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Abstract
Loralai hosts a number of archaeological sites and is considered an important area, where a concentration of prehistoric archaeological sites was noted in previous research. For this purpose, the GIS spatial analysis methods, such as Buffer, K-means clustering and heat map, were used to understand the distribution of archaeological sites in the landscape. The initial result obtained from GIS and ground surveys in 2020, 2021, and 2022 indicated that the prehistoric people wisely resided in those places of the landscape where they found water and fertile land. The paper shows that natural factors were the reason behind the distribution of archaeological sites in the study area.

INTRODUCTION

A GIS can allow layering of information to assess landscape changes and the plotting of archaeological site placement through time, especially in relation to needed natural resources. This can be helpful in riverine regions where ancient sites change location based on access to water (Timor 2004: 135-144). Statistical data can also be compared in a GIS, which may aid in archaeological predictive models (Symanzik et al., 2000: 470-90). Importing archaeological satellite data into a GIS will give the broadest range of results to a remote sensing project (Limp 2000: 223-226). Balochistan is an important province of Pakistan and is one of the largest in land mass, which extends from western Pakistan into southwestern Iran and southern Afghanistan and separates the open alluvial plains of the Indian subcontinent from the Iranian plateau(Franke 2008: 651). This region is arid today, but it would appear that it might have been wet throughout

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its history, as several archaeological sites have been documented in the region in the previous fieldwork (Jarrige 1991: 34). In addition, no palaeoclimatic studies have been done so far to infer about the past climate. It resided, the first Neolithic culture (Mehrgarh 7000 BC) in Balochistan, where evidence of domestication of plants and animals was developed, and people settled in the Kachi plain area (Jarrige 1993: 25-33). The discovery of Mehrgarh linked this part with the Fertile Crescent after the transition from hunters and gatherers to agriculturalists and herders (Franke 2013: 178). It was considered the earliest village in South Asia (Ibid 2010: 1). Loralai district holds rich archaeological, prehistoric and historic sites potential. It was first highlighted by Fritz Noetling (1893-1898) at sites such as Rana Ghundai and Dabar Kot (Khan et al., 2010: 9). Aurel Stein (Stein 1928: 377-380) later documented several sites in Loralai and Zhob, followed by Brigadier Ross's detailed study of Rana Ghundai (Ross 1946: 291-316). Subsequent contributions include Piggott's analysis of potsherds (Piggott 1950: 118-131) and Fairservis's reevaluation and new site identifications (Fairservis 1959: 287-289). In prior archaeological investigations, the methodology predominantly adopted was descriptive in nature, concentrating mostly on the description of sites and the classification of material culture. Although these studies hold significant merit, they lacked the incorporation of sophisticated analytical methodologies. Specifically, contemporary technology, such as GIS, has emerged as pivotal in modern archaeological research in other contexts. They were not utilized in the examination of this particular region. The current study aims to reconstruct the cultural profile of the area by applying GIS-based spatial analysis techniques. The investigation is specifically concentrated on the Borai and Mekhtar tehsils of Loralai District in Balochistan, Pakistan, to understand the spatial distribution of archaeological sites.

Defining the Study Area

Physiogeographically, Loralai is occupied by rugged mountains and small valleys, which vary in elevation from 900 to 3,000 meters in (Fig. 1).

Figure 1: Elevation of the study area, Loralai district. Courtesy geofolio.org.

The district lies between 29°37′-31°27″ N and 67°43′–70°17′ E (Fig. 2) and comprises two tehsils, Borai and Mekhtar (Fig. 3, Fig. 4) (District Census Report, 1998: 1). Three hill ranges bound it: Damangarh in the north, Kru and Gadabar in the centre, and the Dabar range in the south. The drainage system is dominated by the Anambar River, supported by seasonal rivers. Three major streams-Loralai, Mara, and Sehan and connect with the Anambar River, differing in watercarrying capacity (Imperial Gazetteer of India, 1984: 109).

Figure 2: Map of Pakistan showing different areas of the country. In green, the position of the district Loralai in the northwest part of Balochistan province (Source: District Profile 2017).

The Anambar River, the main river of the district, flows smoothly but floods nearby houses and fields during the rainy season. Seasonal streams with broad channels also traverse Loralai, remaining dry most of the year but filling in the monsoon. The district lacks ponds or lakes, with irrigation dependent on tube wells and kareezes. The Borai Valley, encircled by the Damanghar and Kru ranges, extends westward into Murdarghar, covering about 80 miles with limestone and shale hills. To the northeast lies Sabra Valley, bounded by the Lwara watershed, Sappar, and Torghar ranges, with peaks such as Salai, Narai, Buj, and Hazarghat. In the southeast, Barakan Valley drains into the Rakhni watercourse. Geologically, the district is dominated by Upper Cretaceous formations, with Lower Cretaceous and Jurassic outcrops in the west and north, and stratified sandstone with volcanic pebble beds in the east and southeast. Jurassic limestone forms the high southern mountains near Chinjin, while Triassic rocks occur in the northwest. Eocene strata, notably the Laki series, contain coal deposits (Fig. 5) (Balochistan District Gazetteer Series, Vol II, 1907: 27; District Gazetteer of Balochistan 1997: 482–484). Tengberg and Thiébault analyzed 21 charcoal samples from five Balochistan sites, such as Mehrgarh, Nausharo, Lal Shah, Shahi Tump, and Miri Qalat. It reveals continuous human occupation since the 7th millennium B.C. and shifts in vegetation. Tamarix and Prosopis were common species across sites (Tengberg & Thiébault 2003: 21-63). The region's vegetation includes juniper, macrocode, pistachio on hills, and olive at lower elevations. Phulai (Acacia modesta) grows along the Anambar River into Borai Valley, while ash, myrtle, beer gargantua, bushak, and pamangi serve local needs. Saba and Sargrah are cultivated in Mekhtar, Zahra, and Barad. Wild shrubs include gangu (Orthonopsis intermedia), gangdera (Nerium odoratum), leghunae (Daphne oleoides), trishaw (Artemisia), and makhae (Caragana) in highlands (District Census Report 1998: 3). Fauna comprises wolves, jackals, hyenas, foxes, and abundant mongoose in Barakan. Black bears occur in Surghar, Behu, and Hazarghat, with leopards in Torghar, Behu, and Buj ranges. The Sulaiman range supports mountain sheep and markhor, while Anambar hosts chikor and sisi. Birds include vultures, kites, doves, sparrows, larks, hoopoes, and starlings. Snakes and scorpions are widespread and sometimes fatal (District Gazetteer of Balochistan 1997: 504).

Data

The data on the archaeological sites were collected from a field walking survey conducted in Borai and Mekhtar tehsils of District Loralai in 2020, 2021, and 2022. In the field walking survey 379.8 sq km area was covered, and 27 archaeological sites were discovered and categorized as mounded, scattered, natural hill, cave, building and flat sites.

Methods

To study the distribution of archaeological sites in the landscape of district Loralai, Google Earth Pro and Landsat images were obtained. Besides this, GIS spatial analysis techniques such as Buffer analysis, Heat map and K-means clustering were used to discover the relationships between sites and geomorphological features.

Results and Analyses

The first author attempted to integrate satellite images from Landsat 8, SRTM, and GDEM with GIS spatial analysis methods to address the objectives of the study area. The use of satellite imagery in combination with GIS enables a more accurate and comprehensive assessment of landscape features, settlement patterns, and environmental variables that shaped the distribution of archaeological sites. Spatial analysis, at its core, allows researchers to construct spatial models and generate predictions under different scenarios by analyzing relationships between cultural features and their surrounding environments. The science of spatial analysis involves the systematic application of mathematical, statistical, and computational techniques to interpret patterns and relationships among geographic objects and events. It draws from multiple disciplines, including geography, mathematics, statistics, computer science, and remote sensing, to provide an integrated framework for understanding complex spatial datasets (Viana et al., 2023: 1). In this sense, the particular distribution of settlements across a given landscape can be explained through their spatial association with routes of communication, proximity to resources, or connections to other dwellings and communities, among many other factors (Murrieta-Flores & Gregory 2015: 166). Without adopting an explicitly geographical perspective, such patterns might remain unnoticed, as spatial analysis is specifically concerned with uncovering the associations and patterns that exist both within and between 'layers' of spatial data (MacFarlane 2005: 38). This approach highlights not only the presence of archaeological sites but also their contextual relationships within a broader landscape system. The restoration and reconstruction of sites using GIS spatial analysis methods has therefore gained increasing attention, as it provides valuable insights into the evolution of the man-earth relationship. By reconstructing past landscapes, archaeologists can better understand the interplay between environmental change and cultural adaptation, a research focus that has become a recognized hotspot in the archaeology of sites (Liu, 2007: 20-26). GIS achieves this by handling and integrating data from diverse origins. As MacFarlane 2005: 33) defines, GIS can incorporate data relating to defined geographical places or features, whether represented as points, lines, or areas in vector format, or as grid cells or pixels in raster format, allowing for seamless integration and cross-analysis regardless of data origin. Moreover, GIS is not only designed for the collection, management, and analysis of spatial information but is also highly effective in the processing and interpretation of remotely sensed data (Johnson 2006: 48). Weng further emphasizes its significance, describing GIS as an integrated software package specifically designed for handling geographic data through a comprehensive range of functions. These include data input, storage, retrieval, and output, as well as a wide spectrum of descriptive and analytical processes that enable archaeologists to move beyond simple visualization toward dynamic interpretations of spatial patterns(Weng 2010: 21). Accordingly, GIS is now recognized as a well-established tool in archaeology. However, as (Bintliff 2000: 3-20) and (Bell et al., 2002: 169-186) note, many applications in field survey remain limited to the discussion of data structures, collection routines, processing workflows, or the visualization of static patterns, without fully exploiting the analytical potential of spatial modeling. Nevertheless, the advantages of using GIS to formalize correlations between site locations and both cultural and environmental variables have been acknowledged for more than a decade (Bevan & Connolly 2004: 123-138). These correlations allow archaeologists not only to document settlement patterns but also to model predictive relationships, reconstruct past landscapes, and evaluate the role of environmental constraints and cultural choices in shaping human occupation.

Spatial Distribution of Archaeological Sites

Most of the archaeological sites documented in Borai and Mekhtar are mounds, a common feature in the Balochistan landscape, often located along rivers and streams. During the survey, 27 sites were recorded (Fig.3 and Fig. 4)

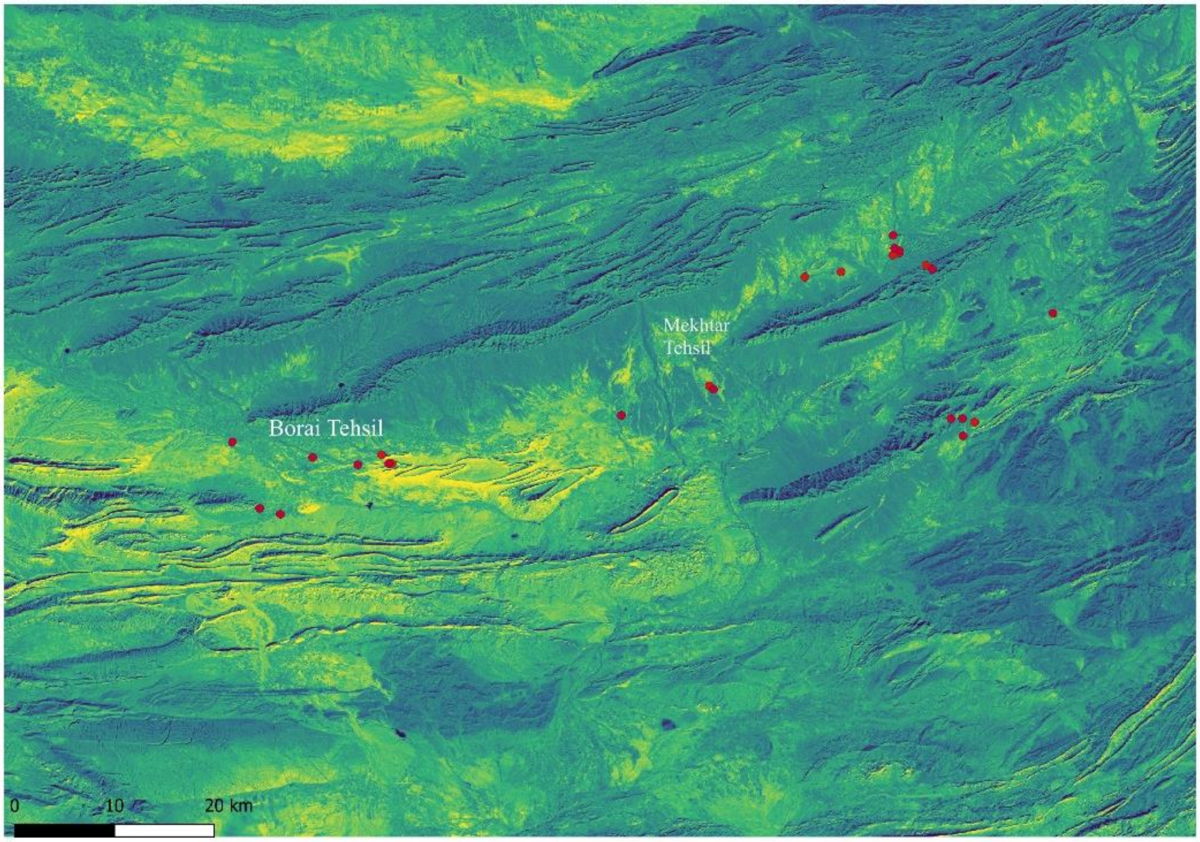

Figure 3: Map showing the distribution of all 27 archaeological sites within the survey areas in the study region. Satellite image Landsat 8 and ASTER GDEM. Courtesy of USGS

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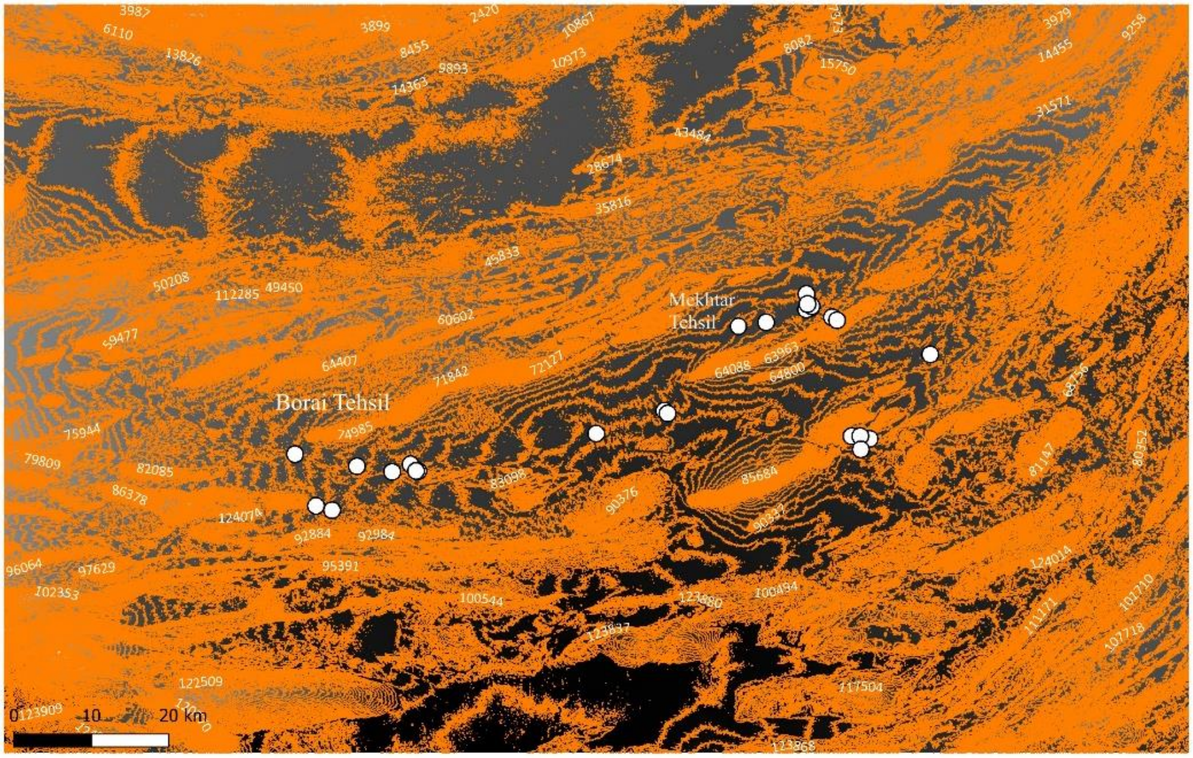

Figure 4: Archaeological sites in white dots with elevation and contour lines. Created in ASTER GDEM and GIS

5.1.1 Mounds

Nine archaeological mounds were documented with handheld GPS in Borai and Mekhtar tehsils (Fig. 5) and (Table 1). These sites remain largely intact, though impacted by local treasure hunters. The distribution differs between the two tehsils: Borai mounds are more dispersed, while those in Mekhtar are more clustered. The broader clustering patterns of mounds are addressed in the following section.

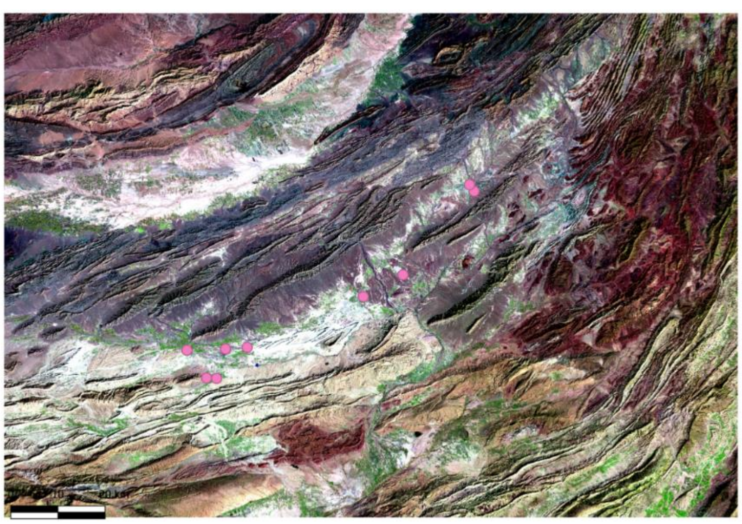

Figure 5: Distribution of archaeological sites in pink dots as mounds in the landscape

Site Name	Longitude	Latitude
Mughal Ghundai Ghabarga	69.020994	30.45363
Shakareez Ghundai	68.5218	30.3991
Saggar Ghundai	68.652	30.3755
Mughal Ghundai Pathan Kot	68.55	30.3301
Balosano Ghundai	68.6049	30.383
Sarmalak Ghundai	68.925364	30.4266
Landa Ghwaz Pathankot	68.5715	30.3241
Manda Ghundai Kishkai Hamzazai	69.214411	30.59708
Zara Kalam	69.20755	30.61328

Table 1: Mounded Archaeological Sites

5.1.2 Flat Sites

Flat archaeological sites in the study area are located in open-air settings, and these sites are highly vulnerable to weathering and disturbance from human and animal activities. A total of 7 flat sites were documented (Table 2), distributed across both Borai and Mekhtar tehsils (Fig. 6). Unlike earlier surveys, this category of site was not previously reported.

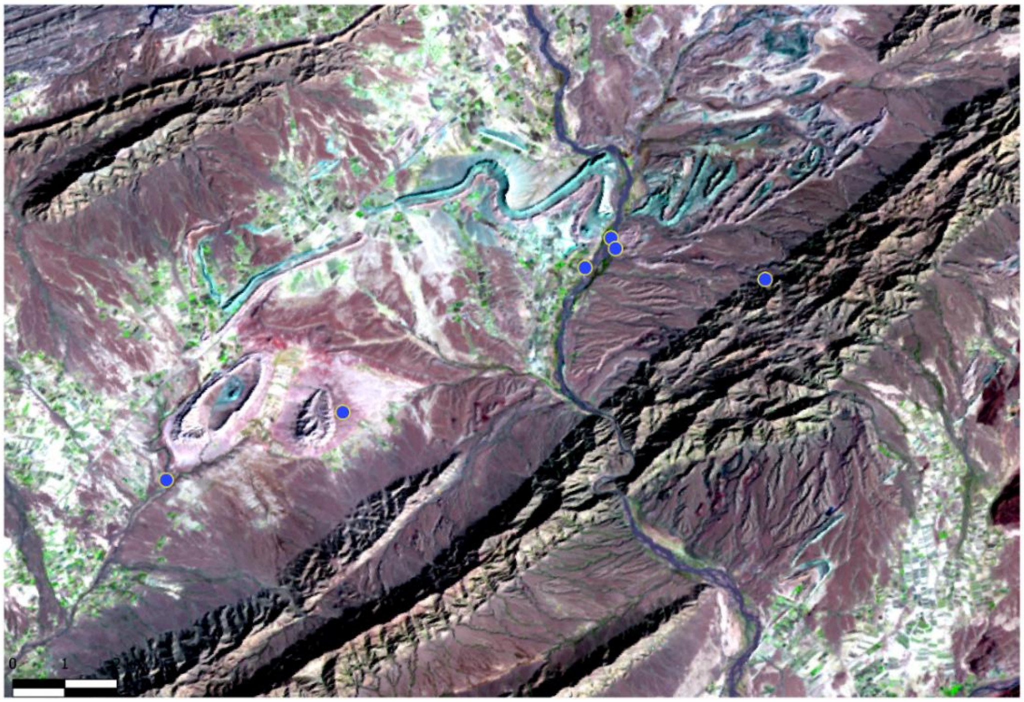

Figure 6: Distribution of archaeological sites in blue dots as flat in the landscape.

Site Name	Longitude	Latitude
Maindan Site Barad	69.153567	30.57537
Kaka Koor site	69.116133	30.57013
Kishakai Hamzazai site Zhara Thana	69.213639	30.59722
Kishakai Hamzazai stone site	69.214036	30.59496
Moza Sabarwala Zara Thana	69.207256	30.5926
Ponga Stone site	68.683978	30.38009
Barad Site near the mountain	69.241803	30.58223

Table 2: Flat archaeological sites

5.1.3 Caves Sites

The next category of sites consists of caves that yielded cultural materials inside or near their entrances, primarily stone tools associated with past human activity. During the survey, 3 cave sites were recorded-2 in Mekhtar and 1 in Borai tehsils (Table 3). All were situated in limestone mountains and natural hills, with cultural remains recovered. The density of caves is low, reflecting the region's geology (Fig. 7).

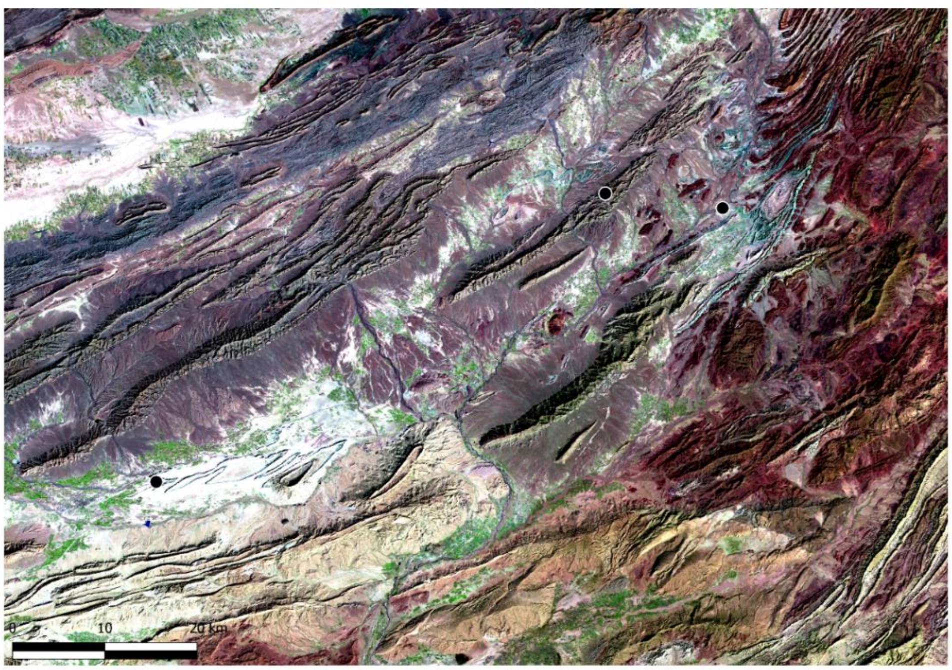

Figure 7: Distribution of archaeological sites in Black dots as caves in the landscape

Site Name	Longitude	Latitude
Mandao Cave (Hyena Den)	69.248544	30.57819
Ponga Cave site	68.683978	30.37663
Mekhtar Cave Naly Azam	69.373456	30.53252

Table 3: Cave archaeological sites

5.1.4 Scattered Sites

Another category consists of 5 scattered archaeological sites documented in the area (Table 4). These sites show a high density of cultural materials dispersed over a wide surface, making their exact extent uncertain. They lack structural remains but yielded pottery, stone tools, and kiln waste. The distribution is shown in (Fig. 8).

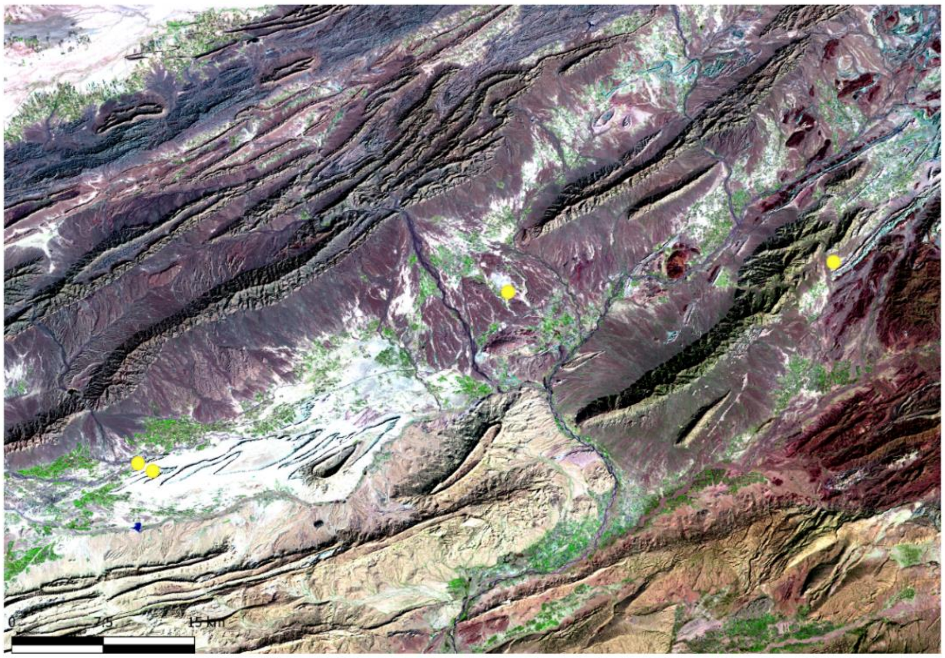

Figure 8: Distribution of archaeological sites in yellow dots as scattered in the landscape

Site Name	Longitude	Latitude
Dargai Sarwaz2	69.292269	30.419572
Site near Cave Ponga	68.687114	30.376561
Dam Site Dargai Kudezai	68.6765	30.3856
Ghabarga Killi site near dry stream	69.016428	30.457136

Table 4: Scattered archaeological sites

5.1.5 Building Sites

Out of 27 sites, 2 were categorized as building sites, both located in Mekhtar tehsil (Table 5; Fig. 9). These revealed stone foundation walls, rooms, and other structural features during the survey. They were disturbed by human activity and illegal excavations. Pottery and stone tools were also recorded from their surfaces. No such sites were found in Borai tehsil.

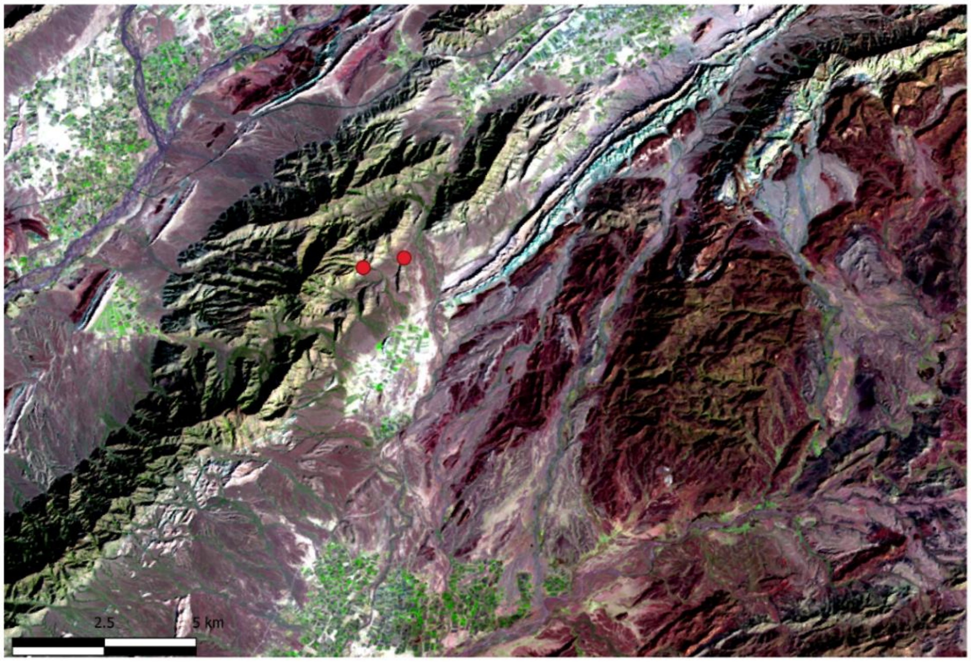

Figure 9: Distribution of archaeological sites in red dots as buildings in the landscape

Site Name	Longitude	Latitude
Mughal Bary	69.267803	30.42325
Dargai Sarwaz1	69.279678	30.4233

Table 5: Building archaeological sites

5.1.6 Natural Hill Sites

Natural hill sites were limited to Mekhtar tehsil, where hilltops and slopes were selected for habitation (Fig. 10). Two sites were recorded (Table 6). One yielded abundant pottery and stone tools spread over a wide area, while the other showed fallen walls visible on Google Earth Pro and produced cultural materials during the survey. The latter site had also been disturbed by illegal excavations

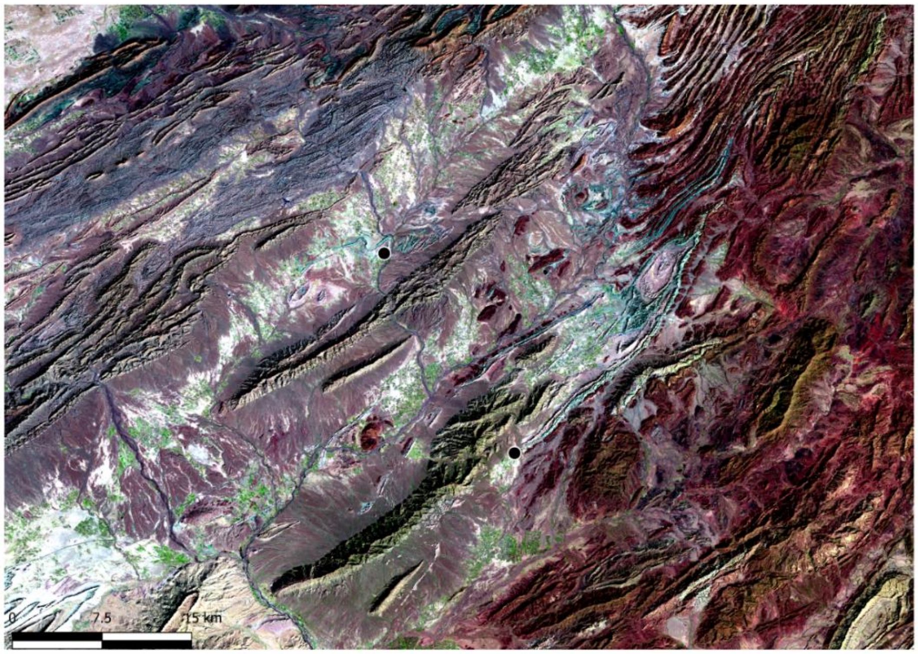

Figure 10: Distribution of archaeological sites in black dots as natural hills in the landscape

Site Name	Longitude	Latitude
Thas Ghundai Moza Cheng Chungai	69.208983	30.599878
Dargai Shapylo near Chamalang Road	69.280303	30.405389

Table 5: Natural hill archaeological sites

5.2. Spatial Analysis in GIS

5.2.1 Buffer Analysis

A buffer polygon is a spatial analytical tool that represents the area within a specified distance from a given object or feature. For instance, if a buffer is generated with a distance of 5 km, the resulting polygon encompasses all territory lying within 5 km of the defined object, effectively delineating a spatial influence zone (Lloyd 2010: 47). The width of such buffers is not necessarily uniform and can be modified to reflect localized environmental and geomorphological conditions. In certain contexts, a wider buffer may be warranted in areas with steep slopes, fragile ecosystems, or zones of environmental sensitivity, ensuring that the analysis accounts for terrain variability and ecological constraints. The development of predictive modelling in archaeology, driven by both research objectives and cultural resource management imperatives, has encouraged the adoption of statistical and spatial techniques to identify potential site locations on the basis of ecological and environmental variables (Schwarz & Mount 2006: 155). Within this framework, buffer analysis has emerged as a key methodological instrument. In the present study, a buffer zone or radius area was systematically demarcated around identified archaeological sites in order to encapsulate the geological, geomorphological, and ecological characteristics within the designated circumference.

A buffer radius of 1 km was selected as the operative scale. This choice is methodologically justified, as it corresponds to a practical distance for pedestrian traversal, thereby reflecting the potential range of daily human movement and resource exploitation in the past. The terrain enclosed within these buffers was examined with reference to its topography, which is predominantly flat to gently undulating. While such conditions generally facilitate mobility, subtle variations in relief can influence patterns of navigation, land-use, and settlement distribution. The

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buffers, when applied to the archaeological sites in the Borai and Mekhtar tehsils of Loralai District, revealed significant spatial patterns (Fig. 11 and Fig. 12). The analysis demonstrated that the sites are not isolated entities; rather, they exhibit a degree of interconnectivity, often located in proximity to perennial or seasonal water resources. Furthermore, the buffers highlighted the presence of zones with relatively dense vegetation, suggesting that ecological productivity may have been a determining factor in site selection. This spatial clustering and environmental association provide valuable insights into the adaptive strategies of past communities, underscoring the role of buffer analysis as a methodological bridge between archaeological data and landscape context.

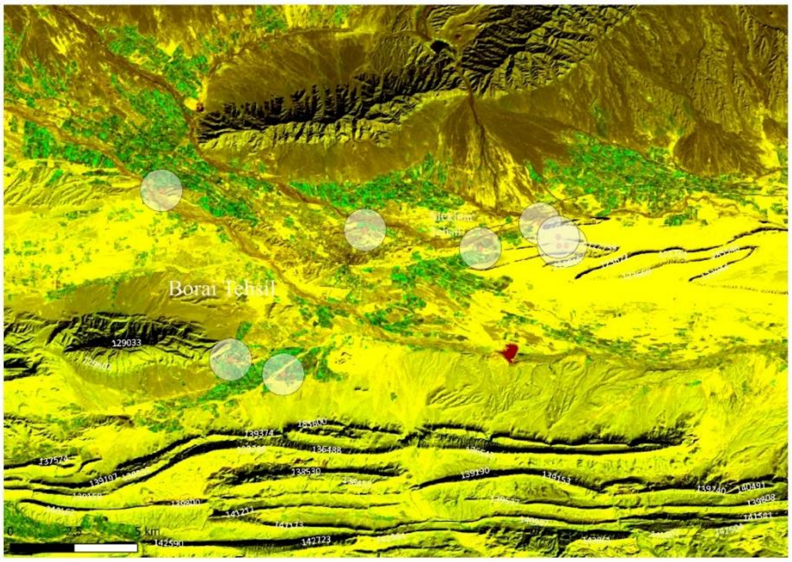

Figure 11: The Borai region, and the contours show elevation. The sites surveyed are shown in red with a 1km circular buffer zone to demonstrate the proximity to water and vegetation. Landsat 8 image.

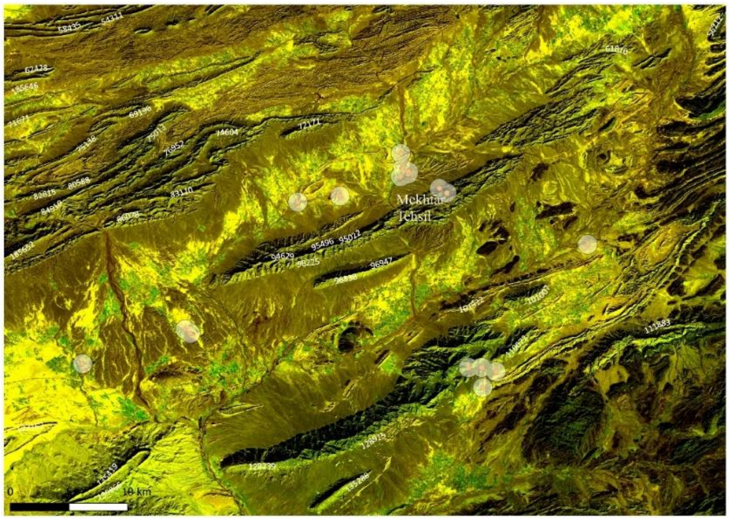

Figure 12: The Mekhtar region, and the contours show elevation. The sites surveyed are shown in red with a 1km circular buffer zone to demonstrate the proximity to water and vegetation. Landsat 8 image.

5.2.2 Heat map and K-means Clustering

Ripley's K-function represents a powerful statistical tool in spatial analysis, with the advantage of characterizing spatial relationships across multiple distance scales. Unlike the nearest-neighbour analysis, which evaluates spatial dependency only at the nearest-event level, Ripley's K enables the assessment of spatial clustering, randomness, or dispersion simultaneously at a range of distances (Dixon 2001: 1-16). This multi-scalar property renders it particularly valuable in archaeological applications, where site distributions are often influenced by complex environmental and cultural factors operating at different scales. The K function is not only applicable for simple point distributions but can also be extended to construct multivariate spatial models, thereby accommodating more complex datasets that include several archaeological or environmental variables (Haining 1993: 615-616). In parallel, cluster analysis constitutes a family of algorithms designed to detect natural groupings within multivariate datasets. The principle underlying cluster analysis is to partition data into internally homogeneous groups that are simultaneously distinct from one another (Davis 2002: 487). Within archaeological contexts, this technique assists in identifying settlement hierarchies, site catchment groupings, or culturally meaningful clusters of activity areas. A distinction must be made between global clustering tests, which search the entire study area for patterns of spatial association, and focused clustering tests, which use prior information about potential causal factors or hypothesized centres of activity. Examples of such focused tests include the score statistic and Stone's test, which assess whether clustering occurs around specific known locations (Lawson 1993: 363-377). The interpretative strength of Ripley's K lies in its comparative framework: the empirical distribution of point data is evaluated against theoretical models of complete spatial randomness (CSR). Deviations from the CSR baseline carry interpretative weight: significant positive departures suggest clustering, whereas significant negative deviations indicate uniformity or over-dispersion, regardless of the overall shape or boundaries of the study area (Conolly & Mark 2006: 166). In other words, the K-function provides a robust and scale-independent measure of whether archaeological sites are statistically aggregated, randomly distributed, or systematically dispersed. Beyond Ripley's K, clustering tests in general not only quantify the overall tendency of geographic events to concentrate in space, but also evaluate their statistical significance. This distinction is important: identifying a cluster does not simply mean observing a group of proximate sites, but rather establishing, through statistical testing, that the pattern differs meaningfully from random expectation. Clusters, in this context, are those localised zones where events or in archaeological terms, sites occur with greater density than elsewhere in the study region (Gyoungju et al. 2010: 135). For the present analysis, a combination of heat mapping and K-means clustering was employed to elucidate the spatial distribution of archaeological sites within the study area. The heat map provides a continuous visual surface of density variation, highlighting areas of high and low site concentration, while the K-means algorithm partitions sites into discrete clusters based on their spatial proximity and statistical similarity. The integration of these two techniques offers a complementary framework: while heat maps reveal gradations of density across the landscape, K-means clustering organizes discrete settlement clusters, both of which contribute to a shaded understanding of settlement organization. The results demonstrate that the spatial distribution of sites is scale-dependent. Within a 2 km radius, a significant degree of clustering is observable, suggesting that sites were deliberately located in proximity possibly to optimize access to water, arable land, or other critical resources. Conversely, beyond the 2 km threshold, the distribution tends towards dispersion, indicating that inter-cluster spacing was maintained, perhaps to minimize territorial overlap or resource competition. This duality of clustering at short distances and dispersion at larger scales underscores the structured nature of settlement organisation, pointing to both localized aggregation and regional planning in site placement. As visualized in (Fig. 13) and Fig. 14) clustering tendencies within the 2 km buffer are readily apparent, while (Fig. 15) illustrates, through an X–Y scatter plot and associated statistical outputs, the interplay of clustering and dispersion across the broader study region. Collectively, these results demonstrate that the archaeological sites are neither randomly scattered nor uniformly spaced.

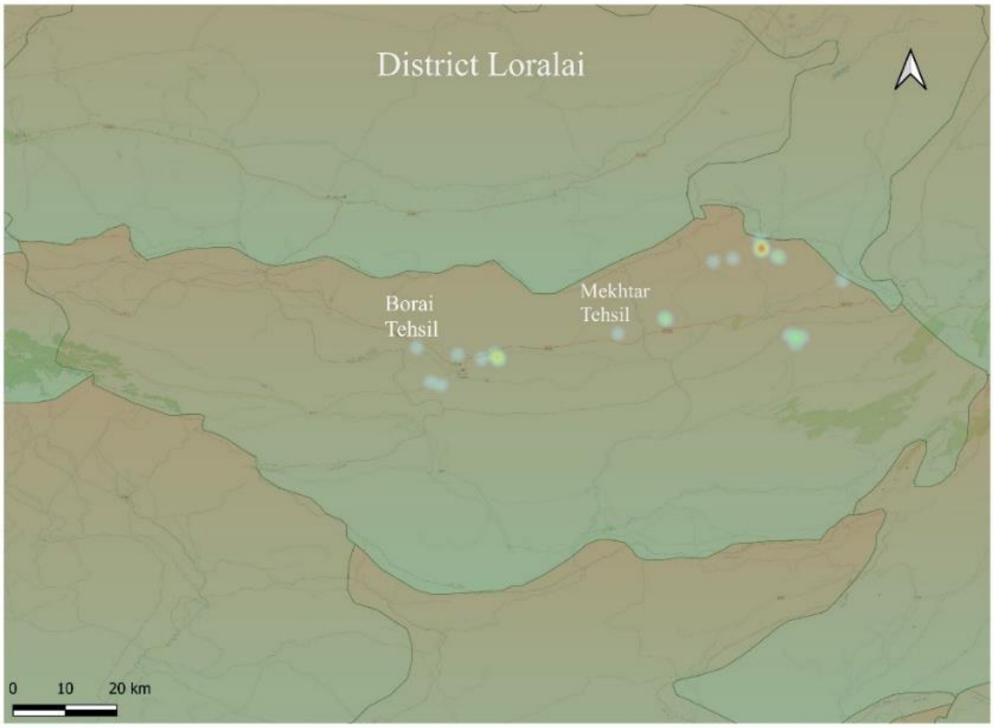

Figure 9: Heat map of archaeological sites in the Loralai district. Courtesy GIS.

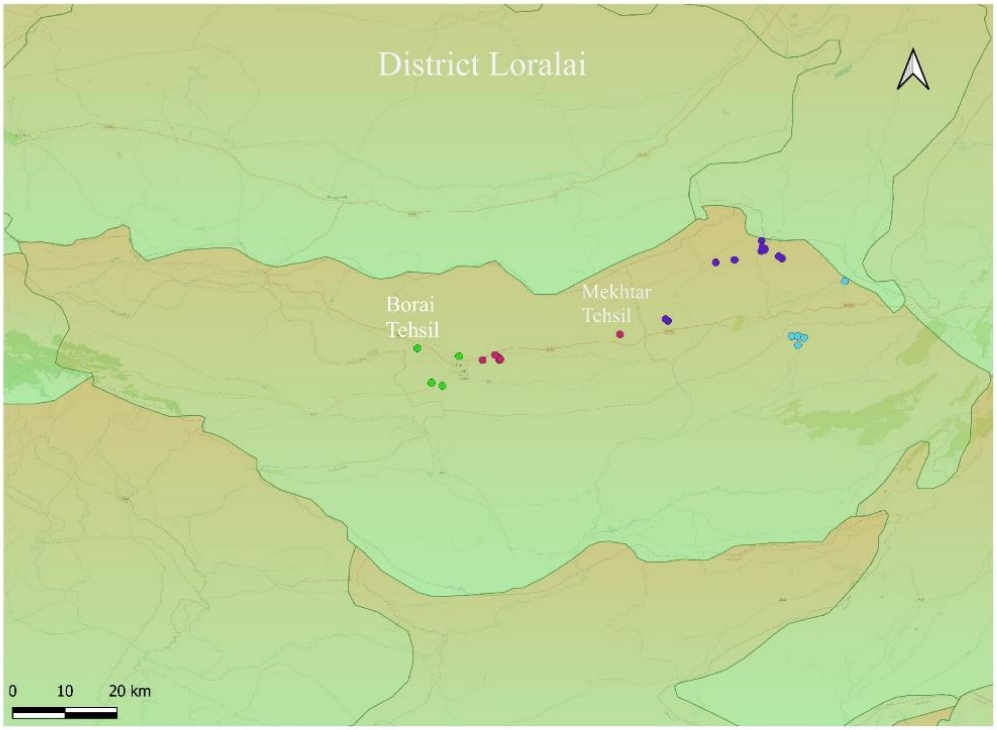

Figure 9: K clustering map of archaeological sites in Loralai district. Courtesy GIS.

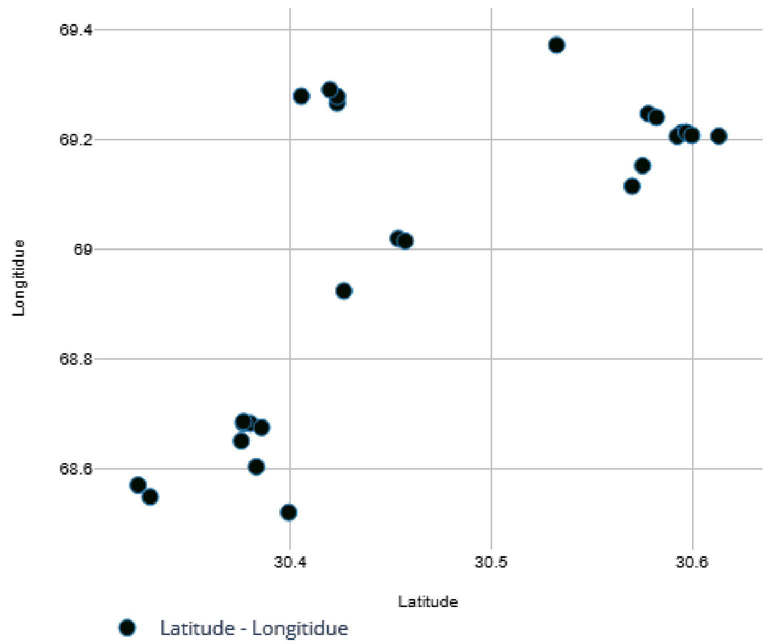

Figure 10: Scattered plot showing clustered and dispersed points or archaeological sites. Courtesy GIS

Discussion

The rationale behind this research work is rooted in the understanding that prehistoric peoples were closely tied to their natural environment, and that this environment played a decisive role in shaping their choices regarding the location of archaeological sites. In order to examine these relationships, Geographic Information Systems (GIS) spatial analysis tools such as buffer analysis, K-means clustering, and heat maps were employed to map and evaluate the distribution of archaeological sites within the study area. As (Ian Hodder 1977: 34) has argued, spatial analysis in archaeology provides clarity in identifying and demonstrating spatial trends, patterns, and relationships within archaeological data. Several case studies illustrate this growing potential. For instance, (Morehart 2012: 2541-2551) examined ancient Chinampa landscapes in the Basin of Mexico, where the integration of GIS and remote sensing allowed for the detailed mapping, reconstruction, and analysis of complex agricultural systems in relation to their surrounding environment. Similarly, (Gao et al., 2009: 333-340) applied GIS techniques in the lakeshore region of Chaohu Lake, China, to assess spatial distribution patterns of archaeological sites, highlighting how both environmental and cultural factors influenced settlement location. In the Argentinean Pampas, (Castillejo et al., 2018: 669-668) employed Ripley's K Function, a spatial statistical tool within GIS, to analyze the Otamendi site. Their work demonstrated how this method can determine whether the distribution of archaeological features reflects clustering, dispersion, or random placement, thereby adding a quantitative dimension to archaeological spatial interpretation. The same combined approach of GIS and remote sensing was also applied in the Awsard area of Morocco, where (Nsanziyera et al., 2018: 1-21) showed how these techniques are effective for detecting, documenting, and preserving archaeological resources in arid desert environments. Beyond settlement mapping, GIS spatial analysis and remote sensing have also been successfully applied to the reconstruction of transportation systems. For example, (Canilao 2020: 75) used these tools to identify possible transportation corridors and past movement patterns in Northwestern Luzon, integrating spatial datasets with landscape features to understand how natural topography and human decision-making shaped route selection. Likewise, in the Cures Sabini archaeological area, predictive modeling techniques were applied to systematically analyze 88 archaeological sites (Espa et al., 2006: 147-155). This study demonstrated how spatial modeling can estimate site location probabilities, offering insights into settlement distribution, land-use patterns, and the interaction between environmental variables and human occupation. Climate change must also be considered when evaluating site distribution, since shifts in climate directly affect human settlement. Aurel Stein observed that there has been a significant decrease in rainfall in Baluchistan since prehistoric times, which likely influenced patterns of settlement dispersal (Aurel Stein 1931: 5-6). The findings of the present study suggest that the dispersion of archaeological sites is closely linked to arid conditions: prehistoric populations tended to relocate toward areas where fertile soils and water were available. Therefore, many sites were located near the rivers, while sites in other places were noted as few. Fresh water has consistently been a critical factor for human occupation across time and space (Yang et al., 2014: 746-766). This pattern is particularly evident in Baluchistan, where regions such as Kolwa, Welpat Tehsil in Las Bela, the Quetta Valley, and the area around Dukai in Loralai contain high site densities due to their relative abundance of water and cultivable soils (Fairservis 1961: 8). Similarly noted that the presence of large mounds in northern Baluchistan corresponded to areas with perennial water supply (Aurel Stein 1929: 90-91). Elevation also plays a significant role in the distribution of archaeological sites. Local elevation serves as a measure of roughness and influences where sites were located (Heilen et al., 2013: 333). Archaeological sites are found both on low and high elevations, reflecting careful choices made by ancient populations. High elevations were often selected for strategic reasons: they offered protection from natural hazards, predatory animals, and potential human threats. At the same time, low-lying areas near water sources were attractive for agricultural productivity. The slope of the terrain is another important parameter. Slope, as (Canning 2005:6-15) notes, is a direct function of topography. However, the analysis indicates that slope played a less significant role in site selection, as steep slopes are difficult to build upon and are prone to erosion, which hinders the preservation of sites. Consequently, fewer sites were found on hill slopes, with the majority located on more stable terrain. To end this discussion, it would be reasonable that human factors would play a vital role in the distribution of archaeological sites while transforming the natural land for productive and economic purposes.

Conclusion

To conclude, this study was primarily grounded in GIS spatial analysis, with a strong emphasis on how natural factors influenced the distribution of archaeological sites across the landscape of the Loralai district. The results obtained from GIS were further substantiated through field investigation, which served as an essential component in verifying and contextualizing the spatial patterns identified digitally. The analysis indicates that the spatial distribution of sites was not random; rather, it was closely tied to natural determinants of the environment, resulting in both dispersion and clustering of sites across the district. The evidence suggests that prehistoric communities made conscious and strategic choices when selecting settlement locations, opting for areas that allowed them to exploit available natural resources efficiently. As GIS spatial analysis and field walking methods were used in the investigation of this area, these two methods could be used in future research to familiar oneself with natural resources and how the prehistoric people accessed and obtained the natural resources and used them in daily activities. Through these methods, one can infer the man and land relationship.

REFERENCES

Bell, T., Wilson, A., & Wickham, A. (2002). Tracking the Samnites: Landscape and communications routes in the Sangro Valley, Italy. American Journal of Archaeology, 106(2): 169-186.

Bevan, A., & Conolly, J. (2004). GIS, archaeological survey, and landscape archaeology on the island of Kythera, Greece. Journal of Field Archaeology, 29(1–2): 123-138.

Bintliff, J. (2000). Beyond dots on the map: Future directions for surface artifact survey in Greece. In J. Bintliff, M. Kuna, & N. Venclová (Eds.), The future of surface artifact survey in Europe : 3-20.

Canning, S. (2005). “BELIEF” in the past: Dempster-Shafer theory, GIS and archaeological predictive modelling. Australian Archaeology, 60: 6-15.

Canilao, M. A. P. (2020). Remote sensing the margins of the gold trade: Ethnohistorical archaeology and GIS analysis of five gold trade networks in Luzon, Philippines, in the last millennium BP (BAR International Series 2988). BAR Publishing.

Castillejo, A. M., Gómez Romero, F., Landa, C., & Barcia García, C. (2018). Archaeological spatial analysis and GIS in a small fortification: Ephemeral occupations along the border during the "Conquest of Desert" process in Argentinean Pampas (19th century). Journal of Archaeological Science: Reports, 18:679-688.

Conolly, J., & Lake, M. (2006). Geographical information systems in archaeology. Cambridge: Cambridge University Press.

Davis, J. C. (2002). Statistics and data analysis in geology (3rd ed.). New York: John Wiley.

Dixon, P. M. (2001. December 20). Ripley's K function. Department of Statistics, Iowa State University.

District Census Report Loralai. (1961). Islamabad: Population Census Organization Statistics Division, Government of Pakistan.

District Census Report Loralai. (1981). Islamabad: Population Census Organization Statistics Division, Government of Pakistan.

District Census Report Loralai. (1998). Islamabad: Population Census Organization Statistics Division, Government of Pakistan.

District Gazetteers of Balochistan. (1997). Quetta: Gosha-e-Adab (Vol. 2).

District Profile Loralai. (2011). Quetta: Planning and Development Department, Government of Balochistan.

Espa, G., Benedetti, R., De Meo, A., Ricci, U., & Espa, S. (2006). GIS based models and estimation methods for the probability of archaeological site location. Journal of Cultural Heritage, 7(3):147-155.

Fairservis, W. A. (1959). Archaeological surveys in the Zhob and Loralai districts, West Pakistan (Vol. 47, No. 2). New York: American Museum of Natural History.

Fairservis, W. A., Jr. (1961). The Harappan civilization-New evidence and more theory. American Museum Novitates, 2055: 1–24.

Franke-Vogt, U. (2008). Baluchistan and the borderlands. In D. M. Pearsall (Ed.), Encyclopedia of archaeology Vol. 1: 651–670.

Gao, C., Wang, X., Jiang, T., & Jin, G. (2009). Spatial distribution of archaeological sites in lakeshore of Chaohu Lake in China based on GIS. Chinese Geographical Science, 19(4): 333-340.

Haining, R. (1993). (Review of the book Statistics for spatial data, by N. Cressie). Computers & Geosciences, 19(4): 615–616.

Heilen, M., Leckman, P. O., Byrd, A., Homburg, J. A., & Heckman, R. A. (2013). Archaeological sensitivity modeling in southern New Mexico: Automated tools and models for planning and management (p. 333). Albuquerque, NM: Statistical Research Inc.

Hodder, I. (1977). Spatial studies in archaeology. Progress in Human Geography, 1(1): 33-65.

Imperial Gazetteer of India Provincial Series: Balochistan. (1984). New Delhi: Usha Publications.

Jarrige, J.-F. (1993). The early architectural traditions of Greater Indus as seen from Mehrgarh, Baluchistan. Studies in the History of Art, 31, Symposium Papers XV: Urban Form and Meaning in South Asia: The Shaping of Cities from Prehistoric to Precolonial Times, 25-33.

Jarrige, J.-F. 1991. Mehrgarh : Its Place in the Development of Ancient Cultures in Pakistan. Jansen, M & Mulloy, M & Urban, G (eds.), Forgotten Cities on the Indus. 34-50

Johnson, J. K. (Ed.). (2006). Remote sensing in archaeology. Tuscaloosa: University of Alabama Press.

Khan, F., Knox, R., Thomas, K., Petrie, C., & Morris, J. (2010). The investigation of early villages in the hills and on the plains of western South Asia. In C. Petrie (Ed.), Sheri Khan Tarakai and village life in the borderlands of north-west Pakistan. Oxford: Oxbow Books.

Khromykh, V., & Khromykh, O. (2014). Analysis of spatial structure and dynamics of the Tom Valley landscapes based on GIS, digital elevation model and remote sensing. Procedia – Social and Behavioral Sciences, 120: 811-815.

Lawson, A. (1993). On the analysis of mortality events associated with a pre-specified fixed point. Journal of the Royal Statistical Society: Series A (Statistics in Society), 156(3): 363-377.

Lee, G., Yamada, I., & Rogerson, P. (2010). GeoSurveillance: GIS-based exploratory spatial analysis tools for monitoring spatial patterns and clusters. In M. M. Fischer & A. Getis (Eds.), Handbook of applied spatial analysis: Software tools, methods and applications. Springer-Verlag.

Limp, W. (2000). [Review of the book Anthropology, space and geographic information systems, by M. Aldenderfer & H. D. G. Maschner]. Journal of Field Archaeology, 27(2): 223-226.

Liu, J. (2007). Archaeology and geographic information system. Beijing: Science Press.

MacFarlane, R. (2005). A guide to GIS applications in integrated emergency management. Emergency Planning College, Cabinet Office.

Morehart, C. T. (2012). Mapping ancient chinampa landscapes in the Basin of Mexico: A remote sensing and GIS approach. Journal of Archaeological Science, 39(8): 2541-2551.

Murrieta-Flores, P., & Gregory, I. (2015). Further frontiers in GIS: Extending spatial analysis to textual sources in archaeology. Open Archaeology, 1(1): 166-175.

Nsanziyera, A. F., Rhinane, H., Oujaa, A., & Mubea, K. (2018). GIS and remote-sensing application in archaeological site mapping in the Awsard area (Morocco). Geosciences, 8(6): 207.

Piggott, S. (1950). Prehistoric India to 1000 B.C. London: Pelican Books.

Ross, E. J. (1946). A Chalcolithic site in northern Balochistan. Journal of Near Eastern Studies, 5(4): 284–316.

Schwarz, K. R., & Mount, J. (2006). GIS and archaeological site location modeling: Integrating spatial statistics into archaeological data modeling. In M. W. Mehrer & K. L. Wescott (Eds.), GIS and archaeological site location modeling :154-175

Stein, A. (1928). An archaeological tour along the Waziristan border. Geographical Journal, 71(4): 377-380.

Stein, A. (1931). An archaeological tour in Gedrosia (Memoirs of the Archaeological Survey of India, No. 43). New Delhi: Government of India Press.

Symanzik, J., Cook, D., Lewin, N., Majure, J. J., & Megretskaia, I. (2000). Linking ArcView and XGobi: Insight behind the front end. Journal of Computational and Graphical Statistics, 9(3): 470-490.

Tengberg, M., & Thiébault, S. (2003). Vegetation history and wood exploitation in Pakistani Baluchistan from the Neolithic to the Harappan period: The evidence from charcoal analysis. In S. A. Weber & W. R. Belcher (Eds.), Indus ethnobiology : 21-63.

Timor, G. (2004). Space and GIS technology in paleoenvironmental analysis (old maps, satellite images, and digital elevation models in archaeology). Antaeus, 27: 135-144.

Ullman, T., Lange-Athinodorou, E., Göbel, A., Büdel, C., & Baumhauer, R. (2018). Preliminary results on the paleo-landscape of Tell Basta/Bubastis (eastern Nile delta): An integrated approach combining GIS-based spatial analysis, geophysical and archaeological investigations. Quaternary International, 501: 1-15.

Viana, C. M., Boavida-Portugal, I., Gomes, E., & Rocha, J. (2023). Introductory chapter: GIS and spatial analysis. In GIS and spatial analysis. IntechOpen. https://doi.org/10.5772/intechopen.108XXX

Weng, Q. (2010). Remote sensing and GIS integration: Theories, methods, and applications. New York: McGraw-Hill.