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EPIDEMIOLOGY AND GEOSPATIAL DISTRIBUTION OF CUTANEOUS LEISHMANIASIS IN SOUTHERN KHYBER PAKHTUNKHWA: A CROSS-SECTIONAL STUDY IN PAKISTAN

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Abstract

Background: *Leishmaniasis is a disease caused by an intracellular parasite transmitted to humans by the bite of a sand fly. Cutaneous leishmaniasis (CL) is particularly of serious concern in Asia. There is a lack of data in the literature about the distribution of CL in Pakistan, particularly Khyber Pakhtunkhwa (KP).*

Objectives: *To map the epidemiological and geospatial distribution of CL in southern KP, Pakistan.*

Methods: *This Cross-sectional study was conducted in the Leishmania Unit, Khalifa Gul Nawaz Teaching Hospital, Bannu, from October 2024 to May 2025. All patients presenting during the study period with laboratory-confirmed CL were included. A total of 198 confirmed cases met the inclusion criteria. Primary outcomes included demographic and clinical characteristics, as well as*

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the spatial distribution of cases. Geospatial mapping (proportional symbol/bubble maps, point distribution maps, inverse distance weighting (IDW), and kernel density estimation (KDE) heatmaps) was performed to identify disease clustering and hotspots.

Results: *The mean age of participants was 28.47±19.30 years. The majority of cases originated from Karak (70.4%). 31.5% of patients had no formal education. Awareness of leishmaniasis was poor: 11.2% had prior knowledge of the disease, and 9.6% knew its transmission mode.*

Geospatial analysis consistently identified the Karak district as the principal hotspot, with additional clustering in parts of North Waziristan. IDW and KDE heatmaps demonstrated dense focal transmission in southern KP.

Conclusion: *CL in southern KP, especially Karak District, shows marked geographic clustering. Low community awareness and concentration of cases in specific areas highlight the need for targeted surveillance.*

Introduction:

Leishmaniasis is a tropical and subtropical disease caused by an intracellular parasite transmitted to humans by the bite of a sand fly, mainly *Phlebotomus* and *Lutzomyia* (Europe, Northern Africa, the Middle East, Asia, and part of South America); exceptionally, transmission has also been reported as a laboratory accident.[1] According to the World Health Organization (WHO), leishmaniasis is one of the seven most important tropical diseases, and it represents a serious world health problem that presents a broad spectrum of clinical manifestations with a potentially fatal outcome.[2, 3] Leishmaniasis is a disease with a worldwide distribution; it is found in about 89 countries.[4, 5] It is endemic in Asia, Africa, the Americas, and the Mediterranean region. In the American continent, it is mainly a jungle zoonosis (but it can be acquired in semi-desert or cold regions) transmitted by sand flies, mainly of the genera *Phlebotomus* and *Lutzomyia*. Between 12 and 15 million people in the world are infected, and 350 million are at risk of acquiring the disease. An estimated 1.5 to 2 million new cases occur each year, and it causes 70,000 deaths per year.[4,6] Visceral Leishmaniasis (VL), also known as kala-azar, is a clinical form endemic in Bangladesh, India, and Nepal. More than 60% of all VL cases worldwide correspond to South Asia, with a predominance in rural areas. In this respect, in Nepal, approximately 5.7 million people are considered to be at risk and are confined mainly to the Terai region, which borders the VL-endemic districts of the Bihar state in India. Moreover, from 1980 to 2007, a total of 23,368 cases, including 311 deaths, were reported. According to the annual health report of the Department of Health Services in Nepal, the incidence of VL was 2.67 per 10,000 people at risk in 2006–2007.[7]

Cutaneous leishmaniasis (CL) is found in Latin America and, less frequently, in Africa (Ethiopia and Sudan). VL, or kala-azar, is found in Northern and Eastern Africa and in Northern Asia (India, Pakistan, Bangladesh, Nepal, and China), in Southern Europe, and in Latin America.[8]

In Pakistan, the infection is commonly present along the entire Western border of Pakistan. Sindh (area associated with Balochistan), Punjab (Multan and Chakwal), and the Northern Areas of Balochistan. In Pakistan, the status of leishmaniasis has been changed. In parts of the country, both the cutaneous and the visceral types of the disease are being noticed in various parts of the country, including the province of Khyber Pakhtunkhwa (KP).[9]

In Pakistan, leishmaniasis has been reported in the human and animal populations. Human-CL is endemic in several parts of Pakistan and is the second most prevalent vector-borne disease in the country after malaria.[10]

Leishmaniasis is endemic to the southern part of the province of KP. The sole driving force behind this research is to identify the epidemiologically

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high-risk areas in the province with in-depth policy recommendations to target potential areas.

Methodology:

Study Design & Setting:

This Cross-sectional study was conducted at the Leishmania Unit of Khalifa Gul Nawaz Hospital, Bannu, a major tertiary care teaching hospital serving southern KP and receiving referrals from surrounding districts. The study was carried out over an eight-month period from October 2024 to May 2025.

Study Population & Sample Size:

The study population comprised all patients presenting to the Leishmania Unit during the study period. All patients with a confirmed diagnosis of CL were included. Patients with suspected but unconfirmed CL, incomplete diagnostic evaluation, or missing essential clinical data were excluded from the study.

A non-probability convenience sampling technique was employed. A total of 198 confirmed cases of CL were included in the analysis, based on Cochran's formula (Z=1.96, Error= 5%). The sample size consisted of all eligible and confirmed cases presenting during the study period, ensuring comprehensive coverage of the disease burden at the study center within the defined timeframe.

Data Collection Tools:

Data were collected using a structured questionnaire designed to capture demographic and clinical information. The questionnaire was initially developed in English and subsequently translated into Pashto. To ensure clarity, accuracy, and cultural appropriateness, the translated version was pilot tested before formal data collection. Written informed consent was obtained from all participants in both English and Pushto before enrolment. For each confirmed case, demographic variables (age, gender, and place of residence) and clinical characteristics were recorded.

The diagnosis of CL was confirmed based on standard clinical evaluation and laboratory procedures routinely followed at the Leishmania Unit, including microscopic examination of slit-skin smears for the detection of *Leishmania* amastigotes.

Statistical Analysis:

To assess the spatial distribution of cases and identify disease hotspots, the residential address of each patient was recorded at the village level. Geospatial analysis was conducted using Python-based analytical tools. Case location data were cleaned and processed using Pandas, while district boundary shapefiles were managed using GeoPandas.

Continuous spatial density surfaces, like Inverse Distance Weighting (IDW) heatmaps, were generated using interpolation techniques implemented through SciPy, and the resulting surfaces were masked to district boundaries using Shapely to ensure geographic precision. Spatial visualization was performed using Matplotlib for static maps and Folium for interactive mapping. Both proportional symbol (bubble) maps and Kernel Density Estimation (KDE) heatmaps were produced to visualize case concentration and spatial clustering. This combined approach enabled identification of high-incidence hotspots while preserving fine-scale, village-level spatial detail across the southern districts of KP. Data were entered and analysed using SPSS version 27. Quantitative variables were summarized as means and standard deviations, while qualitative variables were expressed as frequencies and percentages.

Ethical approval:

Ethical approval was obtained from the Institutional Review and Ethics Board (IREB) on 20 September 2024 (Ref. No. 38/DiR&MJ/BMC/2024), in accordance with the Declaration of Helsinki.[11] Strict confidentiality of patient information was maintained, and all personal identifiers were anonymized during data entry and analysis.

Results:

Study Characteristics:

Data were collected from a total of 198 participants, with a mean age of 28.47 ± 19.30

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years. The majority were male (n = 139; 69.8%). Districts Karak and Bannu accounted for most cases, with 70.4% and 24.0% of participants originating from each district, respectively. Regarding educational level, 31.5% had received no formal education, 24.3% had completed primary schooling, and a further 24.3% had completed secondary education; only 10.8% held a bachelor's degree. Participants represented a wide range of occupations, with students comprising the largest group (29.4%), followed by unemployed individuals (18.8%). Awareness of leishmaniasis was notably low, with only 11.2% of participants having prior knowledge of the disease and 9.6% being aware of its mode of transmission. A past personal history of leishmaniasis was recorded in 2.5% of participants, while 27.1% reported a positive family history (Table 1).

Table 1: Study Characteristics

	Frequency(n)	*Percentage (%)*
Age		
	28.47 ± 19.30	
Gender		
Female	60	30.2
Male	139	69.8
District		
Bannu	47	24.0
Karak	138	70.4
Lakki Marwat	3	1.5
North Waziristan	8	4.1
Occupation		
Driver	6	3.0
Farmer	5	2.5
Housewife	29	14.7
Labour	28	14.2
Mechanic	8	4.1
Student	58	29.4
Teacher	7	3.6
Unemployed	37	18.8
Others	19	9.6
Education level		
Child	3	2.7
No Formal Education	35	31.5
Primary	27	24.3
Secondary	27	24.3
Matric	7	6.3
Bachelor	12	10.8
Heard about Leishmaniasis		
No	175	88.8
Yes	22	11.2
Knowledge of spread		
No	178	90.4
Yes	19	9.6
Past History of Leishmaniasis		
No	194	97.5
Yes	5	2.5

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Family History of Leishmaniasis		
No	145	72.9
Yes	54	27.1

Geospatial Distribution of Cases:

We have included the geospatial distribution of leishmania cases across Southern KP through various visual figures, as discussed below:

Epidemiological Case-Intensity Map:

The case-density map is a formal bubble map that has classified legends with a range, for showing the intensity of cases in a certain area. We can see that the highest intensity of cases is in the Karak district, followed by North Waziristan. The map is shown in Fig. 1.

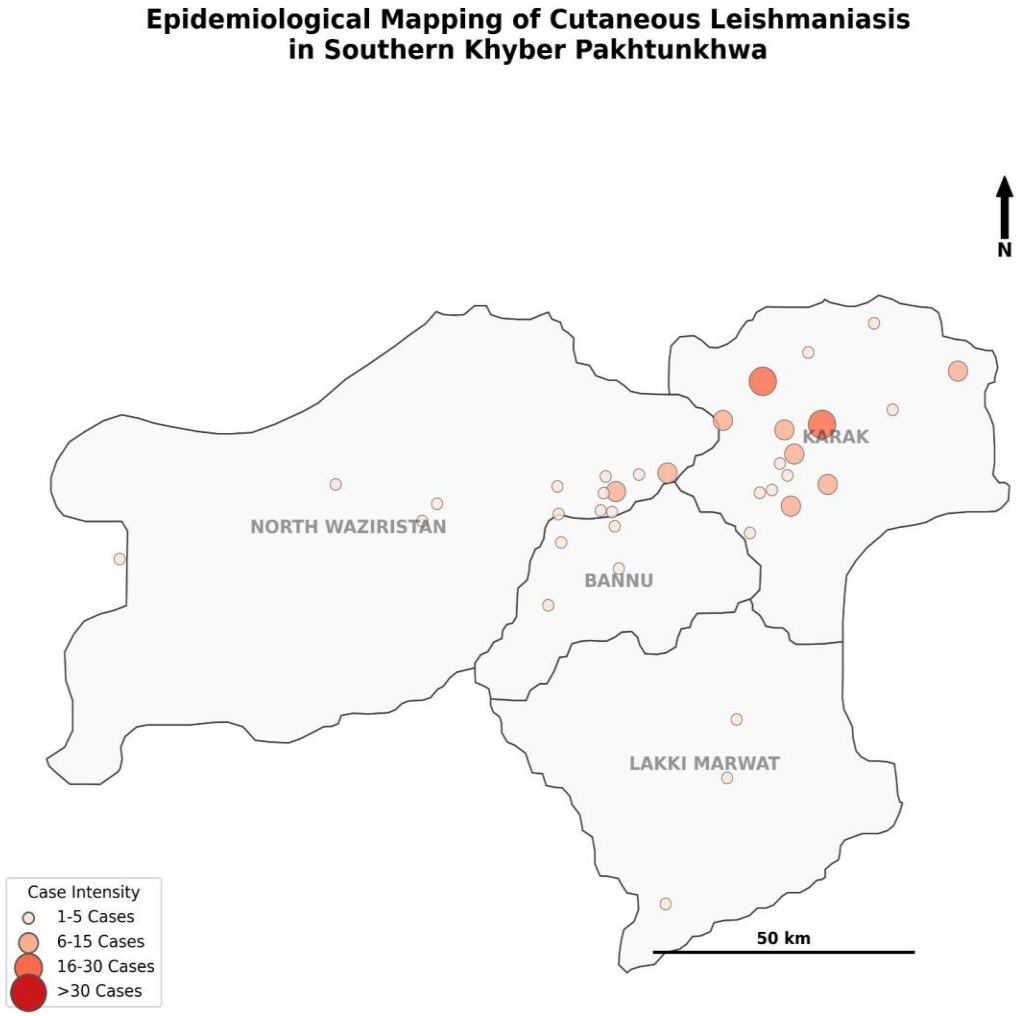


Fig.1 Case-Intensity map of cutaneous leishmaniasis cases in southern KP.

Epidemiological Point Distribution Map:

The point distribution map gives more information by pointing out all area-specific cases on the map, each specifying a village. The highest number of cases is in Karak (28 cases), followed by Bahadar Khel (25 cases). Areas like Bannu township, Fatima Khel, Kakki, etc., had only 1 case in our study, for each area. The map is shown in Fig. 2.

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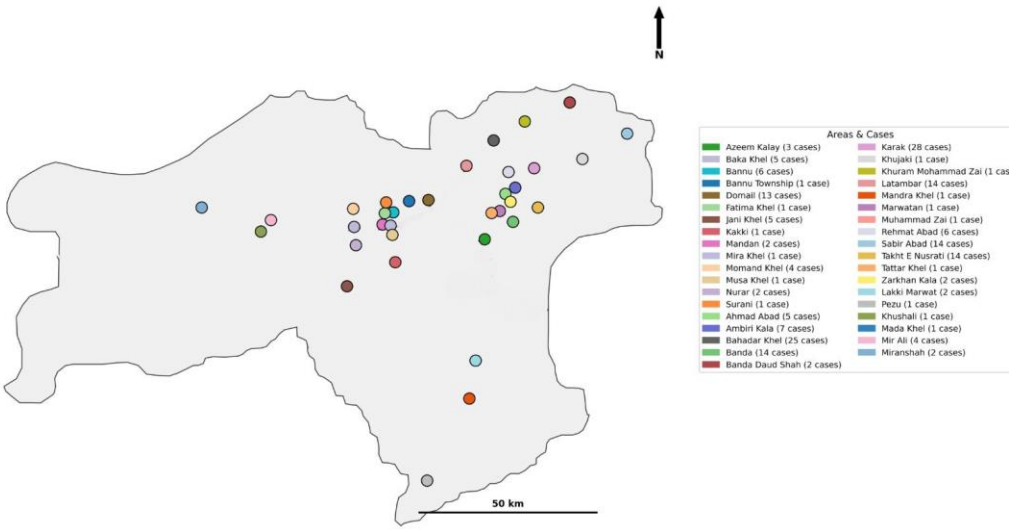


Fig.2 Point Distribution map of cutaneous leishmaniasis cases in southern KP.

Epidemiological Inverse Distance Weighting (IDW) Heatmap:

The IDW map shows the predicted case density across a continuous surface. The continuous surface is a geometrical model of the geographical location used. We can see that the highest density of cases in the heatmap is in the areas of Karak and Bahadar Khel, followed by Latambar. The IDW heatmap is shown in Fig. 3.

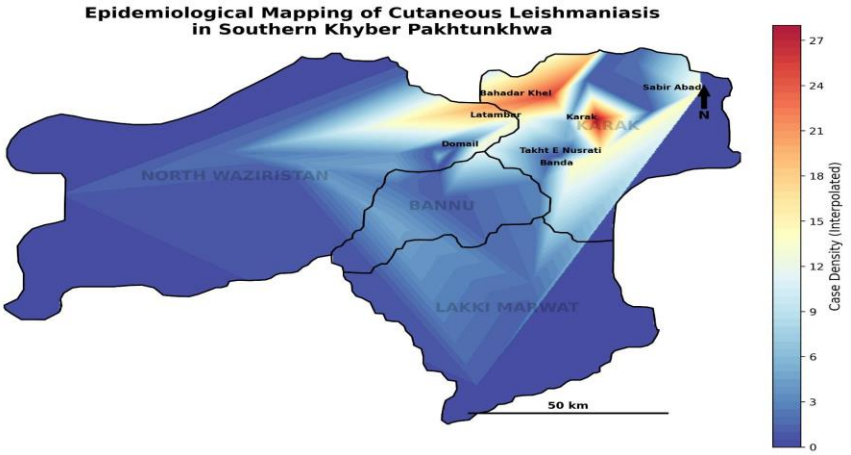


Fig.3 Inverse Distance Weighting (IDW) heatmap of cutaneous leishmaniasis cases in southern KP.

Epidemiological Proportional Symbol (Bubble) Map:

The proportional symbol, or bubble map, shows the distribution of cases, based on the size of circles (bubbles). The larger the circle, the higher the number of cases, and vice versa. As discussed before, District Karak shows the highest number of cases. The proportional symbol heatmap is shown in Fig. 4.

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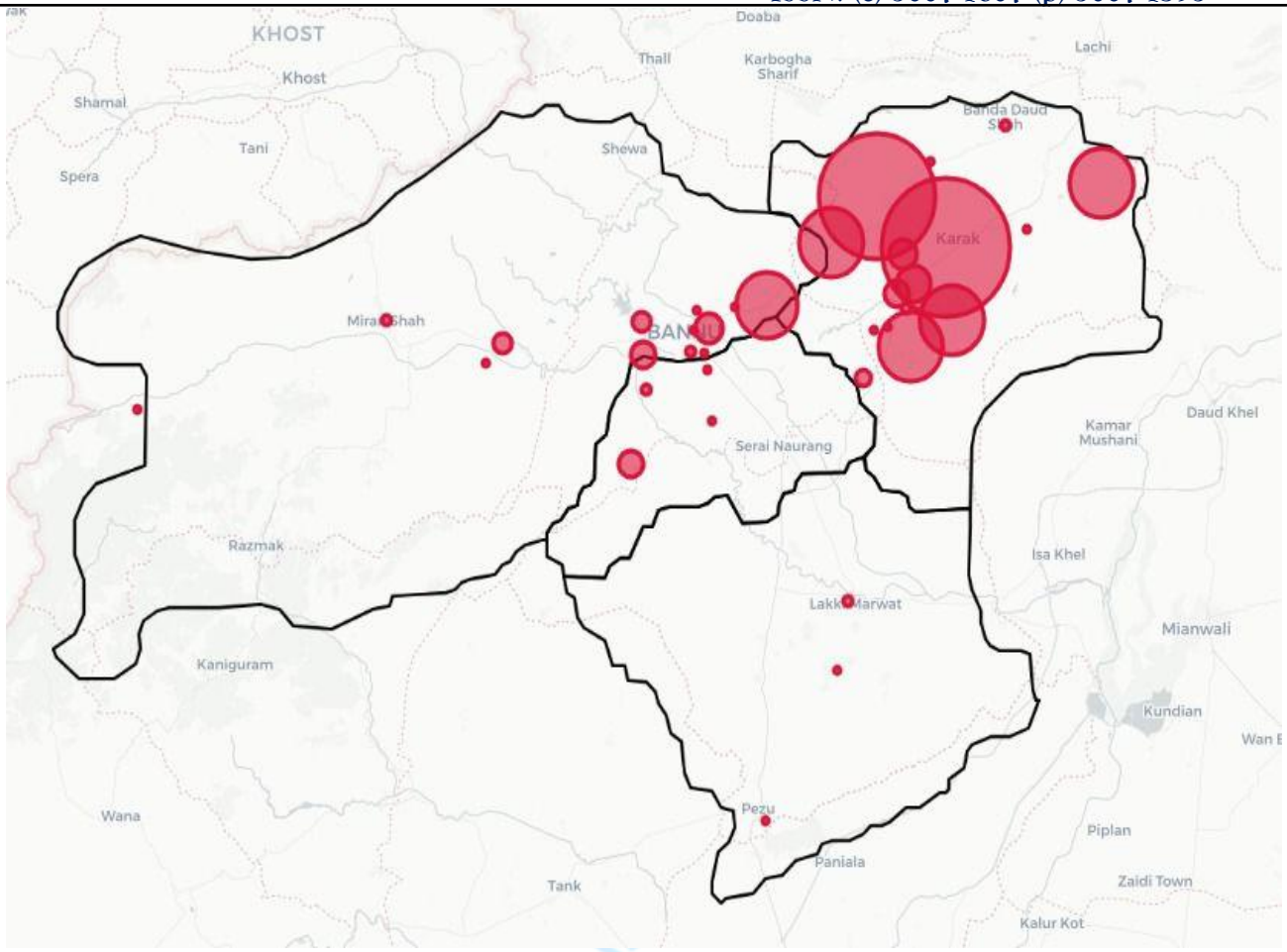


Fig.4 Proportional Symbol (Bubble) map of cutaneous leishmaniasis cases in southern KP.

Epidemiological Kernel Density Estimation (KDE) Heatmap:

The KDE heatmap is another heatmap, which represents the density of cases in a heat-style map. The difference between the KDE and IDW heatmaps is that the IDW heatmap uses interpolated data to form the geometrical illustration, while the KDE heatmap shows hotspots, rather than exact interpolated values. The KDE heatmap is shown in Fig. 5.

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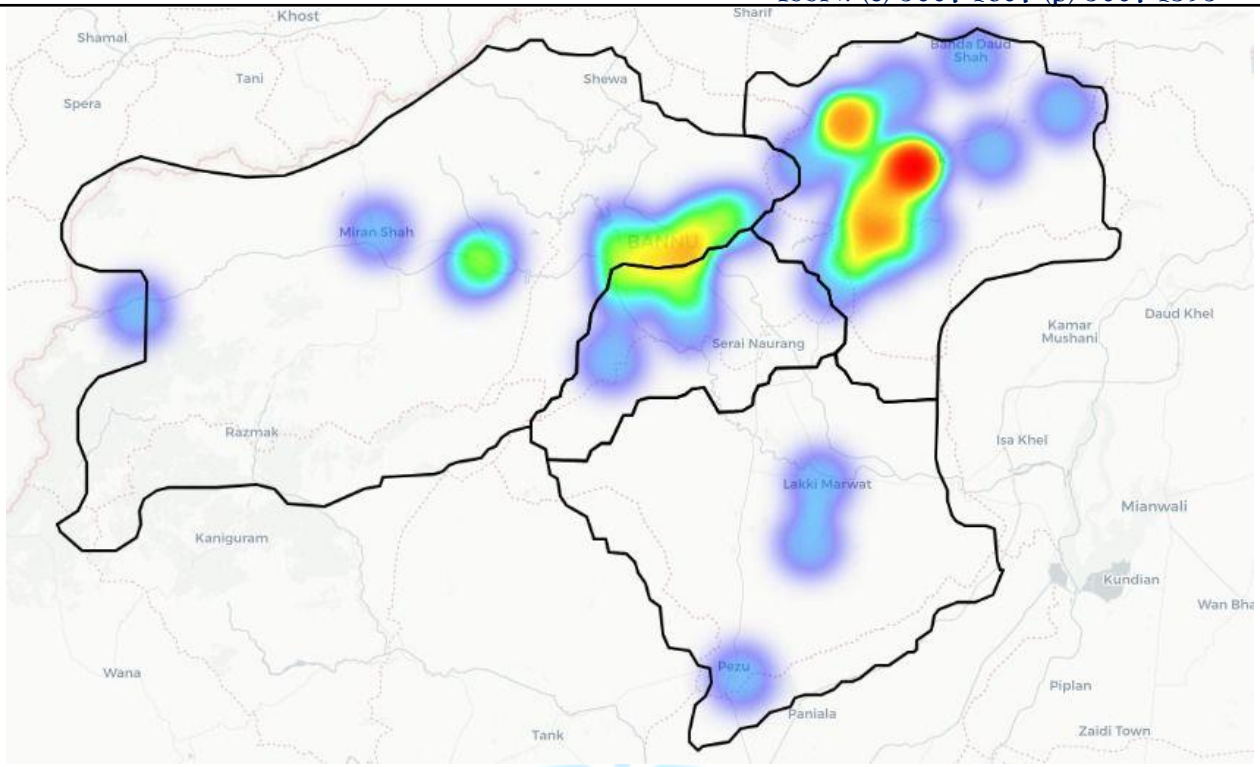


Fig.5 Kernel Density Estimation (KDE) heatmap of cutaneous leishmaniasis cases in southern KP.

Discussion:

To understand and appreciate our findings, it is first important to understand the geography of the region under study. Southern KP is not a homogeneous area. North Waziristan shares a long, porous border with Afghanistan. It has faced consistent armed conflicts and waves of terrorism, and there are close to no facilities in the region. Karak district is arid and rocky and sits inland. It is bordered to the west by North Waziristan and to the north by Kohat. It has no major urban centre and limited secondary healthcare. Bannu, a district to the south, is the divisional headquarters. It is home to the only tertiary hospital serving the whole sub-region. That is why patients from Karak, North Waziristan, and nearby areas travel there for treatment. Even though all these areas are located in southern KP, they differ widely in their environment and demographics.

Karak made up 70.4% of the 198 cases we studied. Following behind, Bannu represented 24.0%. At first glance, one could assume location shaped these numbers, as most participants often arrive from surrounding regions. Bannu is where the Khalifa Gul Nawaz Teaching Hospital is located, yet it landed in second place. Had distance been the main influence, Bannu should have led. But that was not the case. Probably the clearest takeaway is this. Karak's figures reflect actual illness levels across people, not just errors in how cases were logged. In Karak itself, the township recorded the highest individual case count at 28, followed closely by Bahadar Khel at 25, together accounting for over half the district total. We mapped the distribution using several spatial techniques, and each one independently identified the same hotspot in Karak.

What places Karak highest on the list comes down to two factors. One ties directly to landscape features. Rocky slopes, thin shrub cover, and rat holes near homes match ideal living conditions for *Phlebotomus sergenti* and *Phlebotomus papatasi*. Research using geographic models in KP shows these sandfly types stick closely to such environments throughout the region.[12,13] Then there is population movement, notably the steady flows of people crossing from Afghanistan who have settled heavily along this zone. In 1999,

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Rowland et al. reported how settling Afghan refugees in north-west Pakistan raised cutaneous leishmaniasis incidence among local populations.[14] In 2017, Hussain et al. uncovered similar patterns in Kohat, a nearby region, where displaced people from former FATA zones triggered fresh outbreaks. This time, *L. Tropica* was detected in *P. sergenti*, marking its initial provincial confirmation.[15] Karak lies within this same zone. Transmission species are present. People move through here, too. The IDW heatmap also identified Latambar as an area of elevated predicted case density, suggesting transmission may extend into localities beyond the main cluster that sit within the same ecological corridor.

A closer look at North Waziristan shows up as a smaller hotspot but carries weight beyond raw numbers. Reaching the treatment center in Bannu from there is far from straightforward. Roads are rough, checkpoints slow travel, and medical outposts barely exist nearby. In just over two years, Ullah et al. documented 2,603 confirmed CL cases in one clinic in Miranshah.[16] Set beside the few entries labeled North Waziristan here, and the mismatch is stark. This gap reflects a broader pattern seen in conflict-affected zones, where registered case counts fall well below the true burden because the infrastructure needed to record cases breaks down.[16,17]

A look at age and gender revealed patterns tied directly to behavior. Most infected were male, nearly seven out of ten, aligning with findings from similar areas like KP and across the eastern Mediterranean. This trend stems from increased evening activity outdoors, not genetic factors.[12,18] Yet job types showed something less expected. Close to one-third were students. Roughly every fifth person had no employment. One in seven affected were women managing homes. These roles rarely involve fieldwork or long hours outside during daylight. Instead, their common thread lies in being near residences after sunset, when sandflies are most active.[12] The evidence points to one conclusion. Transmission happens close to home, with insects targeting anyone nearby, worker or not.[19] One in forty individuals reported an earlier case of CL. This is not common, yet it remains relevant for upcoming research. Future field investigations might untangle whether setbacks in therapy or repeated contact at home drive new diagnoses.

Concerning the results emerged immediately in the awareness numbers. Just over one-tenth of people could name leishmaniasis before arriving sick at the clinic. Fewer than every tenth person understood that it spread through sandfly bites. Low educational attainment goes some way to explaining this. Around 31.5% had never attended school, and a further 24.3% had completed only primary education, meaning over half the cohort had primary schooling or less. Still, that fact alone misses something crucial. Even though cutaneous leishmaniasis has existed for years across certain areas in KP, knowledge remained weakest where cases piled highest. Southern districts shared this trend, especially Karak.[20] The mismatch stands out clearly when seen alongside infection rates. People facing the highest risk of infection typically lack the awareness needed to identify or act on symptoms. This pattern echoes in the 27.1% of participants reporting affected relatives. Silence around illness in homes lets transmission go unnoticed, lingering month after month until someone finally seeks help.

The more pressing question is what to do with this information. Starting early makes sense. For Bahadar Khel and nearby areas in Karak, actions like indoor spraying and treated bed nets fit well, provided they are timed ahead of the sandfly season. Elsewhere, approaches must shift. In North Waziristan, waiting for reports from Bannu clinics will not show what is really happening on the ground. Instead, moving medical testing and care directly to people works better. The path forward changes with each place. Health education in Pashto, woven into basic medical services, must come first rather than being tagged on later. With current understanding so limited, tackling vectors by itself falls short.[15,21]

This study is, to our knowledge, among the first to map CL at sub-district resolution across southern KP. Most prior work in this region has stayed at the district level. That scale would have missed Bahadar Khel entirely. The data here comes from eight months at a single referral centre, which

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means remote communities, North Waziristan above all others, are not fully captured. That is an honest limitation of how the data were collected. What this study does offer is a geographic baseline. It identifies where the disease is concentrated, which communities are most at risk, and where resources should go first. Community surveys in Karak and Bahadar Khel, sandfly trapping across the identified hotspots, and ecological risk modelling are the steps that follow. This study gives them a place to start.[22]

Strengths and limitations:

- This study provides one of the first detailed geospatial mappings of cutaneous leishmaniasis in southern Khyber Pakhtunkhwa, enabling fine-scale identification of disease hotspots.
- Inclusion of all laboratory-confirmed cases presented during the study period enhances the internal validity and reliability of the findings at a major regional referral centre.
- Use of multiple spatial analytic techniques (Inverse Distance Weighting, Kernel Density Estimation, proportional symbol/Bubble, and point mapping) allowed robust visualisation of clustering patterns and improved epidemiological insight.
- The hospital-based design and non-probability convenience sampling limit the generalisability of results to the wider community and may underestimate the true disease burden.
- The descriptive cross-sectional nature of the study precludes causal inference and does not assess environmental, endogenous, or socioeconomic risk factors associated with transmission.

Conclusion:

Our results conclude that CL in southern KP shows marked geographic clustering, with Karak district representing the highest-risk focus. Low community awareness and concentration of cases in specific localities highlight the need for targeted surveillance, vector control, and public health education. Hospital-based findings provide important baseline data for regional control planning, although community-based studies are warranted to improve generalisability.

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Authorship contribution statement:

Wahab Zia: Conceptualization, Developing Questionnaire, Writing original draft, Statistical Analysis. Waqar Ahmad Tahir: IRB approval, Data Collection, Supervision. Muhammad Farhan Khan: Data Collection, Managing Data Excel Sheet, Questionnaire. Muhammad Maaz Bin Zahid and Abdul Rehman Shahid: Writing-original draft, Writing-review & editing, Validation, Supervision. Shariq Hayat: Writing-original draft. Muneeb-Ur-Rehman: Graphic Designing, Software. Umme Hani: Validation. Gul Zaman: Validation.

Statements & Declaration:

Ethical Considerations:

Ethical approval was obtained from the Institutional Review and Ethics Board (IREB) on 20 September 2024 (Ref. No. 38/DiR&MJ/BMC/2024), in accordance with the Declaration of Helsinki.

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Declaration of competing interest:

None of the authors has any competing interests to declare.

Consent to Participate:

Informed consent was taken from participants in verbal form for their participation in our study.

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Consent for Publication:
Informed consent was taken from participants in verbal form for the publication of our study in our study.

Data Availability Statement:
Data will be provided on request from the authors of the article.

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