Scilight

Environmental Change and Disease Dynamics
https://www.sciltp.com/journals/ecdd

Check for updates

Article

Spatial Epidemiology and Clinical Characteristics of Cutaneous Leishmaniasis in District Lakki Marwat, Pakistan: A Comprehensive Study Utilizing GIS and Entomological Surveys

Javeria Rafiq [1], Farrah Zaidi [1], Salahuddin Khan [2] and Syeda Hira Fatima [3,4,*]

[1] Zoology Department, Peshawar University, Peshawar 25000, Khyber Pakhtunkhwa, Pakistan
[2] Malaria Control Program, Health Department, Peshawar 25000, Khyber Pakhtunkhwa, Pakistan
[3] Global Ecology|Partuyarta Ngadluku Wardli Kuu, College of Science and Engineering, Flinders University, Adelaide, SA 5042, Australia
[4] HEAL Global Research Centre, Health Research Institute, University of Canberra, Canberra, ACT 2617, Australia
* Correspondence: hira.fatima@canberra.edu.au

How To Cite: Rafiq, J.; Zaidi, F.; Khan, S.; et al. Spatial Epidemiology and Clinical Characteristics of Cutaneous Leishmaniasis in District Lakki Marwat, Pakistan: A Comprehensive Study Utilizing GIS and Entomological Surveys. *Environmental Change and Disease Dynamics* **2026**, *1*(1), 7. https://doi.org/10.53941/ecdd.2026.100007

Received: 11 February 2026
Revised: 25 March 2026
Accepted: 14 August 2026
Published: 10 September 2026

Abstract: Objective: The study investigates the Phlebotominae species, epidemiological patterns, and spatial distribution of cutaneous leishmaniasis (CL) in district Lakki Marwat, Pakistan. Method: An entomological survey was conducted in the main city and surrounding union councils (UCs) of Lakki Marwat to characterize Phlebotominae species. Epidemiological data for microscopically confirmed CL cases reported between March 2016 and May 2023 were obtained from the District Health Office, Lakki Marwat. Temporal trends in annual reported case counts were assessed using simple linear regression for the complete reporting years 2017–2022. Annual and cumulative UC-level reported incidence were calculated as cases per 1000 population using the 2023 census population as the denominator, and choropleth maps were generated in R (version 4.4.2) to examine spatial patterns. Results: Among 834 collected Phlebotominae specimens, *Sergentomyia babu* (29.37%) and *Sergentomyia baghdadis* (22.78%) were the most abundant species. A total of 2393 confirmed CL cases were reported during the epidemiological study period. Annual case numbers showed an overall upward pattern across the complete reporting years 2017–2022, with an estimated increase of 61.5 cases per year; however, the temporal trend was not statistically significant ($p = 0.104$, $R^2 = 0.524$). Spatial mapping showed variation in reported CL incidence across UCs, with relatively high incidence observed in some eastern and northern areas of the district, particularly in 2022. Conclusions: This study's findings offer useful insights into the clinical characteristics of the affected population, as well as the epidemiology and spatial distribution of CL in the study area. This information may support targeted epidemiological surveillance, prevention, and control measures.

Keywords: cutaneous leishmaniasis; Phlebotominae; entomological surveys; Pakistan

1. Introduction

Cutaneous Leishmaniasis (CL) is triggered by a protozoan parasite comprising over 20 species in the Leishmania genus. It is a neglected tropical disease spread by infected female Phlebotominae sand flies. Risk factors for CL include precarious housing, poverty, unhealthy diet, and migration [1]. CL is widespread in South

America, the Mediterranean Basin, the Middle East, and Central Asia. Conversely, severe Visceral Leishmaniasis (VL) is prevalent in Brazil, India, and East Africa [2].

In Pakistan, 37 out of 70 species of Phlebotominae have been reported, which can transmit disease to hosts. Phlebotomus papatasi has proven to be the primary vector for causing sandfly fever in West Pakistan [3]. Meanwhile, Phlebotomus sergenti, another vector related to CL, may transmit Leishmania tropica in the region [4]. The region's four recognized clinical forms of leishmaniasis are CL, VL, mucocutaneous leishmaniasis, and post-kala-azar dermal leishmaniasis [5].

CL poses a substantial public health burden in Pakistan, with the highest number of cases reported from Khyber Pakhtunkhwa (KPK), notably in those districts that are along the Afghan border, where the refugees are settled [6]. In Pakistan, approximately 21,700–35,700 cases of CL are documented annually, with frequent epidemics occurring in KPK, Punjab (Multan), Interior Sindh, and Baluchistan [6]. Meteorological factors such as rainfall, humidity, and ambient temperature play a key role in the disease's distribution and vector ecology [7]. With the current climate change, the epidemiology and environmental dynamics of the disease are anticipated to transform considerably [7,8].

This research was undertaken in Lakki Marwat, situated in the southern part of KPK. The region is highly prone to CL due to a combination of geographical, climatic, and environmental factors. It's warm and arid climate with mild winters followed by scorching summers creates optimal conditions for *Phlebotominae* infestations, thereby increasing transmission risk. Impoverished living conditions and insufficient access to healthcare services aggravate disease burden [6].

Prior studies conducted in Pakistan have predominantly focused on clinical case series or localized vector surveys in more accessible urban districts, without integrating entomological, epidemiological, and geospatial data within a single analytical framework [9,10]. Several studies in KPK have documented CL incidence and vector diversity in districts such as Peshawar, Mardan, and Haripur; however, the southern districts including Lakki Marwat have remained disproportionately understudied despite exhibiting comparably high transmission rates [7,9–11].

A key gap in the existing literature is the absence of integrated geographic information systems (GIS) based spatial analysis for CL in Lakki Marwat. While recent global and regional studies have demonstrated the utility of GIS in identifying high-risk transmission zones and informing targeted interventions [12], no such spatially explicit analysis has been applied to this district. Furthermore, the role of environmental determinants including land use, livestock density, housing type, and seasonal climatic variation in modulating vector abundance and disease transmission has not been systematically examined in this locality [8]. The influence of climate change on CL distribution in semi-arid regions of Pakistan also remains insufficiently characterized [8]. Although few epidemiological studies were conducted in Lakki Marwat, they largely neglect vector biology and environmental factors.

The present study is the first to comprehensively investigate CL across all three tehsils and union councils (UCs) of Lakki Marwat, a resource-limited district in KPK. This study integrates entomological surveys, clinical-epidemiological data spanning 2016–2023, and GIS-based spatial mapping to provide comprehensive analysis of the disease. By simultaneously characterizing vector species diversity, disease incidence patterns, high-risk geographic zones, and clinical profiles of affected populations, the study addresses multi-dimensional CL research for this region. The findings are intended to provide an evidence base for targeted surveillance, vector control, and health policy interventions in similarly underserved districts of Pakistan. Despite the high disease burden, molecular characterization and systematic studies on CL in this region remain lacking, highlighting a critical knowledge gap. This study is novel in its integrated use of entomological, epidemiological, and GIS-based spatial analysis to investigate CL in an underrepresented semi-arid district of Pakistan.

2. Methodology

2.1. Study Area

Lakki Marwat lies at 32.36′28.62″ N latitude and 70.54′41.11″ E longitude in southern KPK of Pakistan. It borders the Karak and Bannu districts to the north, the Tank district to the west, the Dera Ismail Khan district to the south, and the Mianwali district of Punjab to the east. It is located near the Afghan border, making it a critical migration and cultural exchange point. The district is a combination of mountains and sandy plains. Lakki Marwat has an arid climate with extremely hot summers (up to 45 °C), mild winters, and low annual rainfall, with most precipitation occurring during the monsoon season. According to the 2023 census, the district's population is 1,040,856, with households of 131,894 [13]. Lakki Marwat's economy is predominantly based on agriculture, with allied livestock breeding and fishing activities accounting for approximately 48.3% of employment. Other significant sectors include community, social, and personal services (18.2%), construction (13.6%), and wholesale retail and restaurant services (9.1%). Rural communities in impoverished districts face disproportionate disease burden due to limited healthcare access and inadequate living conditions [6]. The geographic location of the study area and the surveyed UCs are illustrated in (Figure 1).

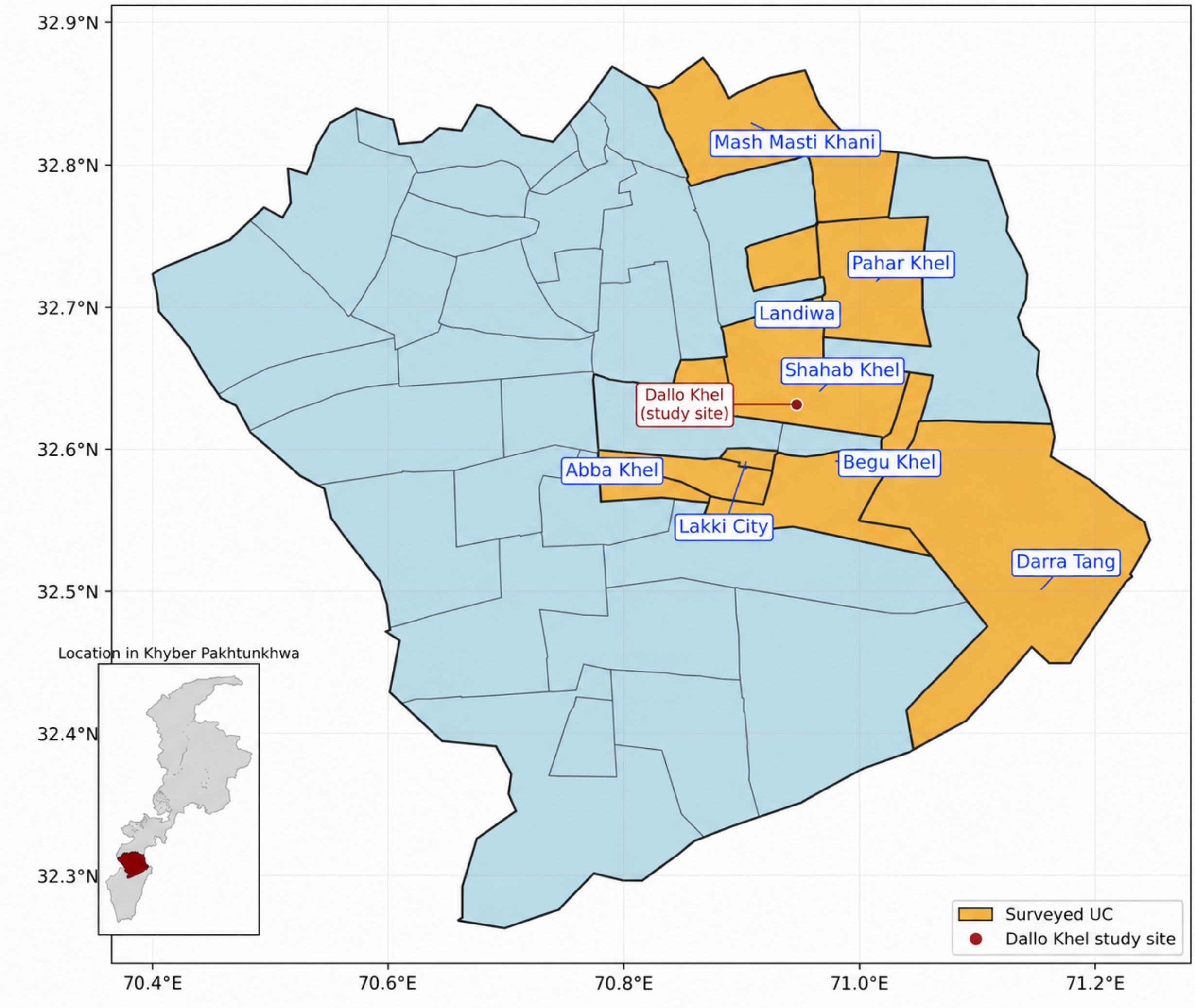

Figure 1. Map of District Lakki Marwat, KPK, Pakistan, showing surveyed UCs including Abba Khel, Pahar Khel, Landiwa, Darra Tang, Mash Masti Khani, Shahab Khel, Dallo Khel (village in Shahab Khan), Begu Khel and Lakki City.

2.2. Data Collection

2.2.1. Species Samples

A cross-sectional ecological survey was conducted from May to December 2019 to characterize the Phlebotomine species present in the study area, including species with recognized vector relevance to CL. The collection was undertaken in Lakki city and surrounding UCs of Abba Khel, Pahar Khel, Landiwa, Darra Tang, Mash Masti Khani, Shahab Khel, Dallo Khel (village in Shahab Khel), and Begu Khel. The Flit method was employed for sample collection, utilizing a hand-operated insecticide sprayer. Samples were gathered from various locations, including mud-plastered rooms, cattle sheds, and washrooms.

Phlebotominae specimens collected from the field were individually placed in Eppendorf tubes containing 70% ethanol and stored at room temperature [14]. Specimens were prepared on glass slides using a fine needle to separate the distal abdomen, wings, and cranium [15]. Puri media was applied to fix the specimens onto the slides, which were then left undisturbed for 1–2 days to allow the fixative to fully penetrate and preserve the sand flies.

Specimens were identified using a binocular compound microscope and taxonomic keys. For female specimens, key diagnostic features included spermathecal segmentation and shape. Male specimens were identified based on genital parts, the number and size of spines on the style, and the size and shape of the aedeagus. For both sexes, pharyngeal armature and cibarium served as distinctive traits for identification [16].

2.2.2. Epidemiological Data

Clinical-epidemiological data (2016–2023) for microscopically confirmed CL patients were obtained at the UC level from the District Health Office in Lakki Marwat, and Vector Borne Diseases Control Program, KPK, Pakistan. UC–level data were unavailable for 2016; therefore, the 2016 data were included only in the district-level descriptive summaries and were excluded from the UC-level incidence and spatial analysis. CL patients were diagnosed, treated, and systematically followed up at local healthcare facilities. However, treatment data was excluded from this study due to incomplete records. Annual case counts were aggregated for descriptive analysis. UC-level incidence calculations are described in Section 2.3. Moreover, seasons were classified according to standard meteorological definitions used by Pakistan Meteorological Department; Spring (March–May), Summer (June–August), Autumn (September–November), and Winter (December–February) [17].

Population data for all UCs were sourced from the 2023 census provided by the Pakistan Bureau of Statistics [13]. Additionally, the distribution of CL cases was analyzed using figures and tables with respect to lesion location and seasonal variations. To analyze and publish these data, a No Objection Certificate was obtained from the DHO Lakki Marwat.

It should be noted that since the collection period did not correspond to the full epidemiological study period of 2016–2023, the entomological findings were interpreted as contextual evidence of local vector presence rather than as a direct measure of annual or UC-level transmission intensity. No direct statistical association was therefore examined between sand fly abundance and the epidemiological data.

2.3. Statistical Analysis

We analyzed the frequency distribution of various Phlebotominae species by sex. For the epidemiological analysis, the distribution of CL cases was assessed based on sex, lesion location, and seasonal variations. A simple linear regression model was used to assess the temporal trend in annual reported CL case counts from 2017 to 2022, with calendar year included as a continuous independent variable and annual case count as the dependent variable. The partial 2016 and 2023 data, covering March to December and January to May for the two years respectively, were excluded from the formal trend analysis because these incomplete reporting periods were not directly comparable with complete calendar years. Regression estimates were reported with statistical significance defined as a two-sided p-value < 0.05.

Annual and cumulative UC-level reported incidence were calculated as the number of reported CL cases per 1000 population, using the 2023 census population of each UC as a fixed denominator.

$$\text{Reported incidence} = \frac{\text{number of reported CL cases}}{\text{UC population}} \times 1000$$

UC-level data were unavailable for 2016; therefore, spatial analyses were restricted to 2017–2023. Annual UC-level population estimates were also unavailable for the study period; therefore, use of the 2023 census population enabled consistent spatial comparison across UCs, although it may under- or overestimate incidence in earlier years due to population change over time. Choropleth maps were created to visualize annual and cumulative spatial patterns of reported CL incidence across the district. Statistical analyses and visualizations were performed using R (version 4.4.2).

3. Results

3.1. Species Identification and Distribution

The collection consisted of 834 Phlebotominae specimens, with females accounting for a greater proportion (n = 442, 53%) than males (n = 392, 47%) in our indoor collection. Among the female specimens, the most abundant species was *S. babu*, followed by *S. baghdadis*. The collected specimens were categorized based on their species and sex. The results are presented in the following Table 1:

Table 1. Distribution of Phlebotominae in Lakki Marwat (May–December 2019).

S. No	Species	Females n (%)	Males n (%)
1.	*S. babu*	145 (32.82%)	100 (25.51%)
2.	*S. baghdadis*	140 (31.67%)	50 (12.76%)
3.	*Ph. sergenti*	45 (10.18%)	120 (30.61%)
4.	*Ph. papatasi*	29 (6.56%)	38 (9.69%)
5.	*S. dentate*	20 (4.52%)	24 (6.12%)
6.	*S. grekovi*	10 (2.26%)	13 (3.32%)
7.	*S. clydei*	10 (2.26%)	12 (3.06%)
8.	*S. sumberica*	10 (2.26%)	13 (3.32%)
9.	*S. babu/baghdadis*	10 (2.26%)	22 (5.61%)
10.	*S. fallax afghanica*	12 (2.71%)	0 (0.00%)
11.	*S. murgabiansis*	11 (2.49%)	0 (0.00%)

3.2. Epidemiological Trends of CL

A total of 2393 confirmed cases of CL were reported between March 2016 and May 2023. Males accounted for 64.8% of reported cases, compared with 35.2% among females (Table 2).

Table 2. Distribution of reported CL cases in Lakki Marwat from 2016 to 2023, by season and sex.

Year	Total Cases n (%)	Spring n (%)	Summer n (%)	Autumn n (%)	Winter n (%)	Males n (%)	Females n (%)
2016 (partial year)	108 (100%)	34 (31.5%)	10 (9.3%)	49 (45.4%)	15 (13.9%) *	68 (63.0%)	40 (37.0%)
2017	251 (100%)	9 (3.6%)	12 (4.8%)	87(34.7%)	143 (57.0%)	165 (65.7%)	86 (34.3%)
2018	92 (100%)	10 (10.9%)	7 (7.6%)	46 (50.0%)	29 (31.5%)	66 (71.7%)	26 (28.3%)
2019	463 (100%)	62 (13.4%)	24 (5.2%)	111 (24.0%)	266 (57.5%)	266 (57.5%)	197 (42.5%)
2020	381 (100%)	73 (19.2%)	75 (19.7%)	97 (25.5%)	136 (35.7%)	254 (66.7%)	127 (33.3%)
2021	354 (100%)	78 (22.0%)	47 (13.3%)	90 (25.4%)	139 (39.3%)	230 (65.0%)	124 (35.0%)
2022	541 (100%)	117 (21.6%)	93 (17.2%)	150 (27.7%)	181 (33.5%)	356 (65.8%)	185 (34.2%)
2023 (partial year)	203 (100%)	106 (52.2%)	NA *	NA *	97 (47.8%)	145 (71.4%)	58 (28.6%)
Total	2393 (100%)	489 (20.4%)	268 (11.2%)	630 (26.3%)	1006 (42.0%)	1550 (64.8%)	843 (35.2%)

Note: * Winter data for 2016 are partial because the study period commenced in March 2016. Summer and autumn data for 2023 were unavailable because the study ended in May 2023. Percentages were calculated using the available cases for each year.

The lower limbs were the most affected body site (41.2%), followed by upper limbs (27%). Lesions of the head and neck region accounted for 25.0% of cases (Figure 2).

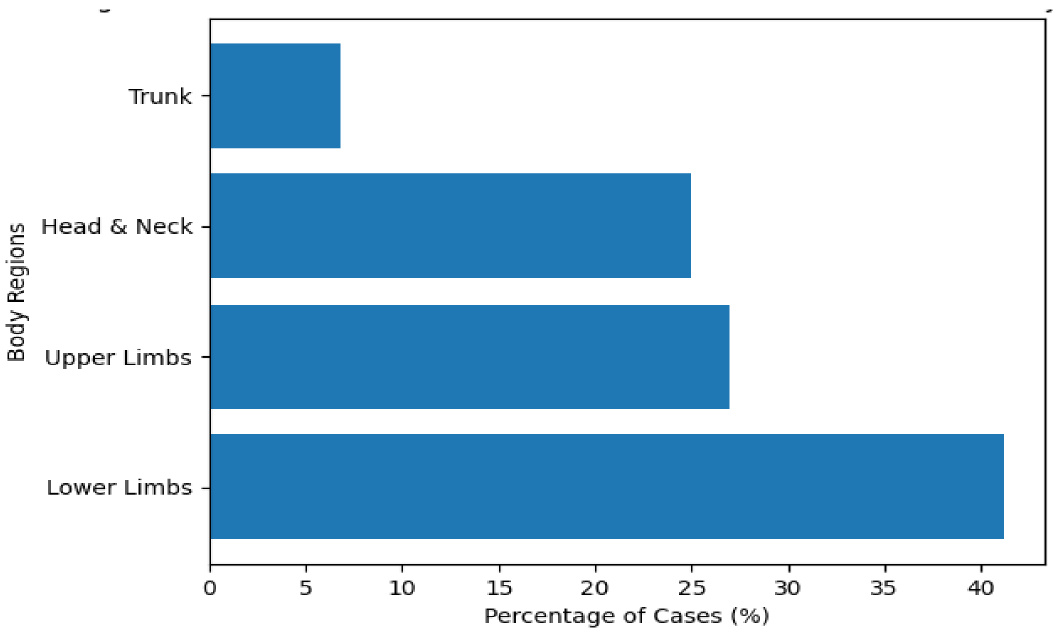

Figure 2. Distribution of CL lesions across body regions. Bars represent the lesions on major body parts including head and neck, upper limbs, lower limbs and trunk.

Annual reported CL cases showed an overall upward trend across the complete reporting years from 2017 to 2022; however, the trend did not reach statistical significance. Linear regression estimated an average increase of 61.5 cases per year ($p = 0.104$) and the model explained 52.4% of variation in annual case numbers ($R^2 = 0.524$). Males consistently accounted for approximately 57–72% of reported cases across years (Table 2). Winter was the dominant season for clinical presentation in 2017 and from 2019 to 2022. For instance, in 2016 and 2018, autumn accounted for the highest percentage of cases. In the partial 2023 data, spring accounted for the largest proportion of reported cases. Across years, summer remains the season with the lowest proportion of reported cases, particularly during 2016–2019 (5% to 9% of annual cases). The seasonal pattern may reflect the incubation period of the parasite, where infections contracted during warmer months may not present as visible lesions until the cooler months (Figure 3).

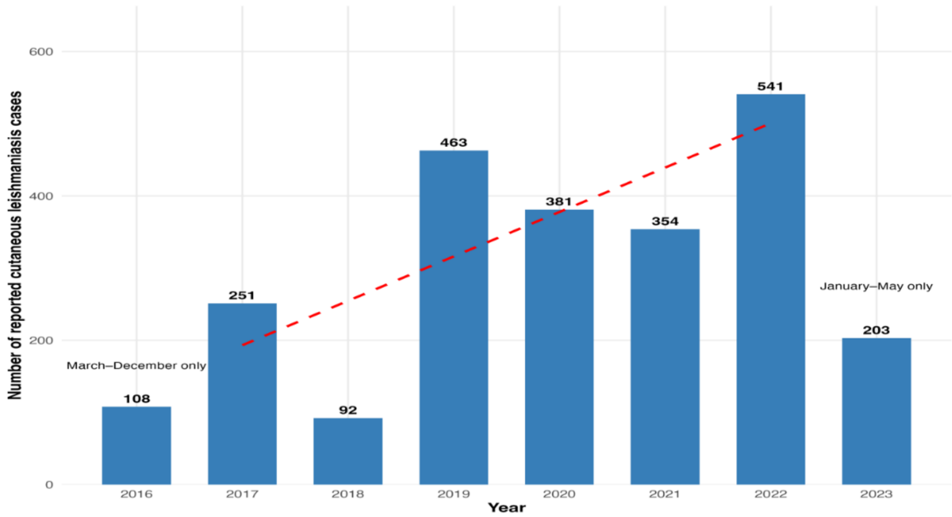

Figure 3. Annual CL cases in Lakki Marwat, KPK, Pakistan. The dashed line represents the fitted temporal trend for the complete reporting years 2017–2022. Data for 2016 cover March–December, and data for 2023 cover January–May.

The choropleth map illustrates cumulative reported incidence across UCs, expressed as reported cases per 1000 population (Figure 4).

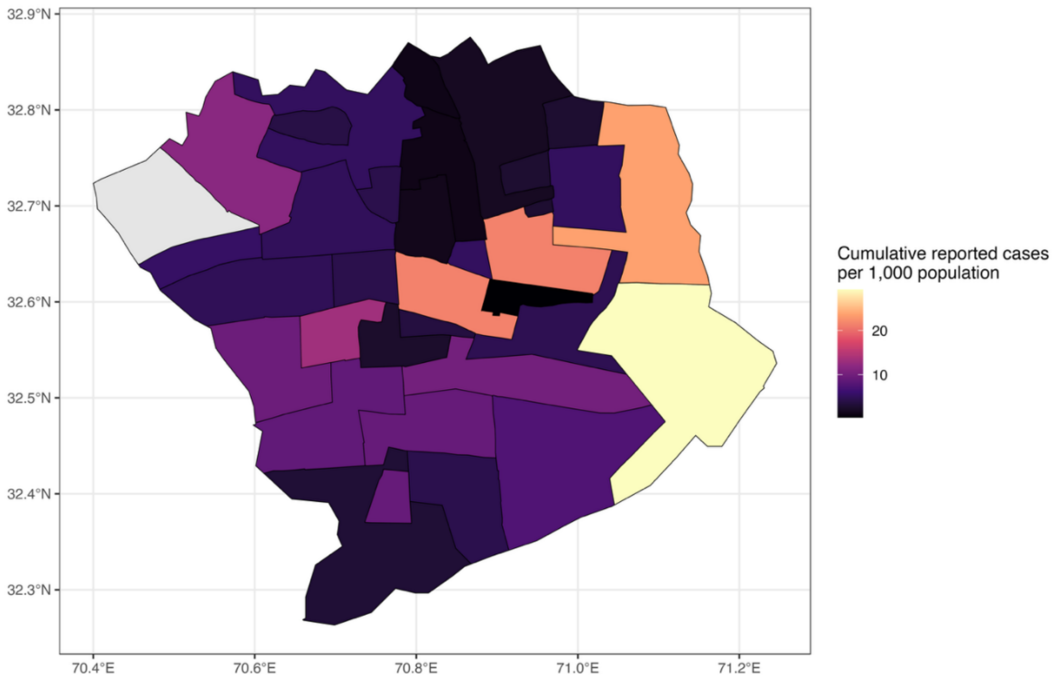

Figure 4. Choropleth map depicting the cumulative reported incidence of CL across UCs of Lakki Marwat, KPK, Pakistan, from 2017 to 2023, expressed as cumulative reported cases per 1000 population using the 2023 census

population as the denominator. Darker shades indicate lower cumulative incidence, while warmer shades indicate higher cumulative incidence, highlighting spatial heterogeneity in the reported CL burden across the district.

The maps reveal shifting areas of relatively high reported incidence, with notable increase in incidence in some eastern and northern regions during 2022 (Figure 5). Environmental conditions may have contributed to this spatial and temporal variation; however, meteorological factors, soil conditions, flooding, and annual sand fly abundance were not directly assessed in this study. Therefore, the observed 2022 pattern should be interpreted as descriptive rather than evidence of a causal environmental effect.

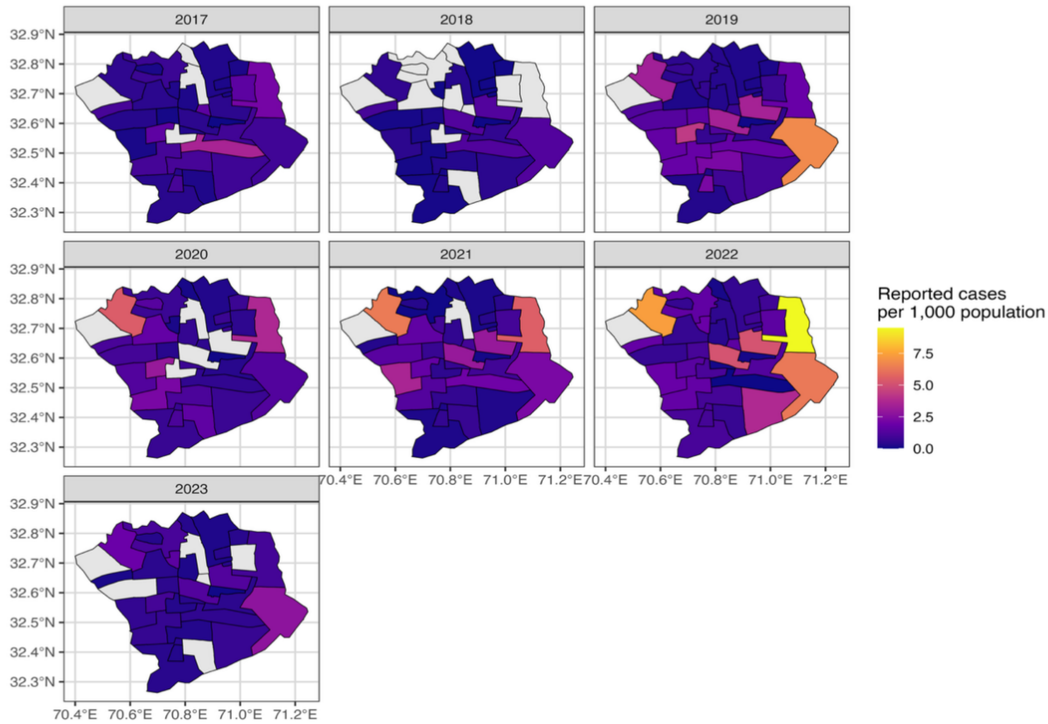

Figure 5. Series of choropleth maps showing annual reported incidence of CL across UCs of Lakki Marwat, KPK, Pakistan, from 2017 to 2023, expressed as reported cases per 1000 population using the 2023 census population as the denominator. Gray areas indicate UCs with unavailable epidemiological data. Data for 2023 cover January–May only.

4. Discussion

This study provides an overview of the epidemiology and spatial distribution of CL in Lakki Marwat. The findings indicate spatial and temporal variation in reported CL cases and describe the Phlebotominae species identified during the 2019 survey. The annual case numbers showed an overall upward pattern, although the temporal trend did not reach statistical significance. The findings also identify northeastern UCs as areas with a relatively high reported burden of CL.

The dominance of *Sergentomyia* species, specifically *S. babu* and *S. Baghdadis,* presents a notable ecological profile for Lakki Marwat. Unlike Lakki Marwat, northern regions in Pakistan, such as district Chitral, have cooler and more humid conditions, with *Ph. papatasi* species as the predominant species, followed by *Ph. sergenti* [18]. Lakki Marwat, by contrast, is characterized by a semi-arid climate, higher temperatures, lower rainfall and extensive sandy plains. Moreover, in neighboring Iran, the dominant genus is *Sergentomyia,* consistent with our findings, and *Ph. kazeruni* is the prevailing species in southeastern Iran [19]. Such differences indicate regional variations in *Phlebotominae* species composition and support the need for a region-specific investigation.

Although *Sergentomyia* species were the most abundant taxa collected in the 2019 survey, their role in human CL transmission in this setting remains uncertain. *Phlebotomus papatasi* and *Ph. sergenti* are the principal recognized vectors associated with human leishmaniasis in Pakistan; therefore, the predominance of *Sergentomyia* in our collection should be interpreted as an ecological finding rather than evidence of its role in transmission.

Annual reported case numbers showed an overall upward pattern from 2017 to 2022; however, this temporal trend was not statistically significant. Therefore, the observed increase should be interpreted as a descriptive pattern rather than evidence of a significant temporal rise. CL was more often reported in males than females, and this male predominance is consistent with findings from other studies [20]. Previous research has suggested that differences in outdoor and occupational exposure may contribute to higher sand fly exposure among males [6], although these factors were not assessed in the present study.

Spatial analysis indicated several UCs with relatively high reported CL incidence. Previous studies have reported associations between sand fly abundance and environmental conditions such as poor sanitation, mud housing, and livestock shelters [21]. The relatively high reported incidence in UCs such as Shahab Khel and Samandi may reflect local environmental, housing, or exposure-related factors; however, these factors were not directly assessed in this study.

Reported cases were most frequent during winter and autumn. This seasonal pattern may partly reflect the incubation period of the parasite, whereby infections acquired earlier may become clinically apparent later. Other studies have reported different seasonal patterns, including higher prevalence during summer [18], highlighting the potential influence of local climatic and ecological conditions. Because these factors were not directly assessed in the present study, the observed seasonal pattern should be interpreted descriptively. Together, these findings provide useful information on the temporal and spatial distribution of reported CL cases and may inform targeted surveillance, public awareness, and seasonal control planning [22].

This study has several limitations. First, UC-level incidence was calculated for 2017–2023 using the 2023 census population as a fixed denominator, because annual UC-level population estimates were unavailable for the study period. This approach enabled consistent spatial comparisons across UCs but may under- or overestimate incidence in earlier years due to population change over time. Second, the Phlebotominae vector survey was restricted to a single transmission season from May to December 2019 and may not fully capture interannual variation in vector density or species composition across the broader 2016–2023 epidemiological period. Therefore, the entomological findings were interpreted as contextual evidence of species presence and were not used to directly explain annual or UC-level incidence patterns. Third, epidemiological data for 2016 and 2023 covered only partial calendar years (March–December 2016 and January–May 2023), limiting direct comparison of annual and seasonal patterns with complete reporting years. These years were therefore excluded from the formal temporal trend analysis.

Ultimately, these results are consistent with broader evidence linking CL with poverty and environmental vulnerability. The integration of GIS data may support health authorities in moving towards more proactive, location-specific surveillance [12]. By identifying areas of relatively high reported incidence in the northeastern part of the district, the local health department may be better able to target surveillance and awareness activities to areas with a higher reported disease burden. While full spatial statistical modeling was beyond the scope of the current study, future research could apply spatial analytical methods such as autocorrelation analysis (e.g., Moran's I), hotspot or cluster analysis, and spatial regression to quantify geographic clustering and identify factors associated with variation in CL incidence. Molecular characterization of Phlebotomine species and analysis of meteorological, environmental and socioeconomic parameters would also improve understanding of transmission patterns and support the development of targeted intervention and community health strategies.

5. Conclusions

This study offers a detailed overview of CL in Lakki Marwat, KPK, Pakistan. Males accounted for the majority of reported cases. Reported cases were most frequently recorded during winter, followed by autumn. GIS-based mapping identified areas with relatively high reported CL incidence and may support targeted public health surveillance and control planning. These findings may help inform measures to reduce the disease burden in the region.

Author Contributions

J.R.: Conceptualization, data curation, formal analysis, writing original draft. F.Z.: Conceptualization, validation, writing review and editing. S.K.: Conceptualization, data review and validation. S.H.F.: Conceptualization, data visualization, validation, writing review and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

The study has been approved by the Research Ethics Board, University of Peshawar, Pakistan under the approval no. REB-03/01.

Informed Consent Statement

Not applicable.

Data Availability Statement

Leishmaniasis data were acquired from District Health Office, Lakki Marwat and the Vector Borne Diseases Control Program, KPK, Pakistan upon request. District Health Office operates at district level while Vector Borne Disease Control Program operates at provincial level. These datasets are not publicly available but can be obtained from data custodians in Directorate General of Health Services, KPK, Pakistan. Population data are publicly available from Pakistan Bureau of Statistics.

Acknowledgments

We appreciate the District Health Office, Lakki Marwat, and the Vector Borne Disease Control Program, Directorate General Health Services, Peshawar, KPK, Pakistan, for making the secondary data available. We sincerely thank Tehmina Jan at the Zoology Department, University of Peshawar, for her expert assistance in specimen identification.

Conflicts of Interest

The authors declare no conflicts of interest.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the authors used ChatGPT (Open AI, 2025) for language editing, grammar checking, and improving clarity of expression. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

1. Abadías-Granado, I.; Diago, A.; Cerro, P.A.; et al. Cutaneous and Mucocutaneous Leishmaniasis. *Actas Dermo-Sifiliogr.* **2021**, *112*, 601–618. https://doi.org/10.1016/j.adengl.2021.05.011.
2. Wamai, R.G.; Kahn, J.; McGloin, J.; et al. Visceral leishmaniasis: A global overview. *J. Glob. Health Sci.* **2020**, *2*, e3. https://doi.org/10.35500/jghs.2020.2.e3.
3. George, J.E. Isolation of Phlebotomus fever virus from Phlebotomus papatasi and determination of the host ranges of sandflies (Diptera: Psychodidae) in West Pakistan. *J. Med. Entomol.* **1970**, *7*, 670–676. https://doi.org/10.1093/jmedent/7.6.670.
4. Rasheed, S.B.; Shah, M.Z. Molecular detection of Leishmania tropica in field-caught Phlebotomus sand flies (Diptera: Psychodidae) from cutaneous leishmaniasis endemic focus of Pakistan. *J. Asia-Pac. Entomol.* **2023**, *26*, 102129. https://doi.org/10.1016/j.aspen.2023.102129.
5. World Health Organization. Leishmaniasis Fact Sheet. Available online: https://www.who.int/news-room/fact-sheets/detail/leishmaniasis (accessed on 10 February 2024).
6. Ullah, W.; Yen, T.Y.; Niaz, S.; et al. Distribution and Risk of Cutaneous Leishmaniasis in Khyber Pakhtunkhwa, Pakistan. *Trop. Med. Infect. Dis.* **2023**, *8*, 128. https://doi.org/10.3390/TROPICALMED8020128.
7. Khan, K.; Wahid, S.; Khan, N.H.; et al. Geospatial and climatic patterns associated with the distribution of sand fly (Diptera: Psychodidae) vectors of leishmaniasis in Pakistan. *J. Med. Entomol.* **2018**, *55*, 626–633. https://doi.org/10.1093/jme/tjx246.
8. Trajer, A.J.; Grmasha, R.A. The potential effects of climate change on the climatic suitability patterns of the Western Asian vectors and parasites of cutaneous leishmaniasis in the mid- and late twenty-first century. *Theor. Appl. Climatol.* **2024**, *155*, 1897–1914. https://doi.org/10.1007/s00704-023-04726-4.
9. Mansoor, A.; Afshan, K.; Nargis, G.; et al. Epidemiology and future risk estimates of cutaneous leishmaniasis in district Dera Ismail Khan, Pakistan: Analysis of data from 2019–2022. *Afr. Health Sci.* **2024**, *24*, 51–64. https://doi.org/10.4314/ahs.v24i4.8.
10. Khan, M.; Ghayyur, S. Distribution, clinical features, and cutaneous leishmaniasis epidemiology: A District Haripur, KPK, Pakistan case study. *Med. Rep.* **2023**, *2*, 100025. https://doi.org/10.1016/J.HMEDIC.2023.100025.
11. Khan, N.H.; Bari, A.U.; Hashim, R.; et al. Cutaneous leishmaniasis in Khyber Pakhtunkhwa province of Pakistan: Clinical diversity and species-level diagnosis. *Am. J. Trop. Med. Hyg.* **2016**, *95*, 1106–1114. https://doi.org/10.4269/ajtmh.16-0343.

12. Zeb, I.; Qureshi, N.A.; Shaheen, N.; et al. Spatiotemporal patterns of cutaneous leishmaniasis in the district Upper and Lower Dir, Khyber Pakhtunkhwa, Pakistan: A GIS-based spatial approach. *Acta Trop.* **2021**, *217*, 105861. https://doi.org/10.1016/j.actatropica.2021.105861.
13. Pakistan Bureau of Statistics. *7th Population and Housing Census 2023: Khyber Pakhtunkhwa, Table 1—Households, Population, Household Size and Annual Growth Rate*; Government of Pakistan: Islamabad, Pakistan, 2023.
14. Sales, K.G.D.S.; Miranda, D.E.D.O.; da Silva, F.J.; et al. Evaluation of different storage times and preservation methods on phlebotomine sand fly DNA concentration and purity. *Parasit. Vectors* **2020**, *13*, 399.
15. Phuphisut, O.; Nitatsukprasert, C.; Pathawong, N.; et al. Sandfly identification and screening for *Leishmania* spp. in six provinces of Thailand. *Parasit. Vectors* **2021**, *14*, 352. https://doi.org/10.1186/S13071-021-04856-6.
16. Wijerathna, T.; Gunathilaka, N. Morphological identification keys for adults of sand flies (Diptera: Psychodidae) in Sri Lanka. *Parasit. Vectors* **2020**, *13*, 450. https://doi.org/10.1186/S13071-020-04305-W.
17. Pakistan Meteorological Department. *Outlook for March–April–May (MAM), 2026*; Government of Pakistan: Islamabad, Pakistan, 2026.
18. Zaidi, F.; Fatima, S.H.; Jan, T.; et al. Environmental risk modeling and potential sand fly vectors of cutaneous leishmaniasis in Chitral district: A leishmanial focal point of Mount Tirich Mir, Pakistan. *Trop. Med. Int. Health* **2017**, *22*, 1130–1140. https://doi.org/10.1111/tmi.12916.
19. Kassiri, H.; Javadian, E. Composition of the sand fly fauna in Khash County, Southeast Iran. *J. Insect Sci.* **2012**, *12*, 132. https://doi.org/10.1673/031.012.13201.
20. Solomon, M.; Fuchs, I.; Glazer, Y.; et al. Gender and Cutaneous Leishmaniasis in Israel. *Trop. Med. Infect. Dis.* **2022**, *7*, 179. https://doi.org/10.3390/TROPICALMED7080179.
21. Calderón-Anyosa, R.; Galvez-Petzoldt, C.; Garcia, P.J.; et al. Housing Characteristics and Leishmaniasis: A Systematic Review. *Am. J. Trop. Med. Hyg.* **2018**, *99*, 1547–1554. https://doi.org/10.4269/ajtmh.18-0037.
22. Bamorovat, M.; Sharifi, I.; Agha Kuchak Afshari, S.; et al. Mutual Role of Patients and the Healthcare System in the Control of Cutaneous Leishmaniasis. *Transbound. Emerg. Dis.* **2023**, *2023*, 7814940. https://doi.org/10.1155/2023/7814940.