



Leishmaniasis in Libya at the Human–Animal–Environment Interface: A Critical One Health Review for Climate-Resilient and Sustainable Control

Nouara Elazirg Elammari^{1*}, Muftah Younis Ali², Ali Amsaed Alhaddad³

1. Department of Parasitology, Faculty of Medicine, University of Benghazi, Benghazi, Libya.
2. Department of Parasitology, Faculty of Medicine, University of Benghazi, Benghazi, Libya.
3. General Practitioner, Jardinah Village Hospital, Benghazi, Libya.

*Corresponding author: nouara.elammari@uob.edu.ly

Article Info

ABSTRACT

ARTICLE HISTORY

Received: 15-07-2026

Accepted: 15-08-2026

Published: 29-08-2026

CITATION

*Nouara E. Elammari.

Leishmaniasis in Libya at the Human–Animal–Environment Interface: A Critical One Health Review for Climate-Resilient and Sustainable Control, *Journal of Novel Pharmaceutical Discoveries (JNPD)*. 1(2), 11-21.

Leishmaniasis remains one of the most consequential neglected vector-borne parasitic diseases, yet its burden is unevenly visible because surveillance intensity, laboratory access and health-system resilience vary markedly between endemic settings. Libya represents a strategically important North African setting in which zoonotic transmission, arid and semi-arid ecologies, population mobility, urban expansion, climate variability and prolonged health-system disruption intersect. This critical narrative review synthesises contemporary Libyan, North African and international evidence on epidemiology, parasite–vector–reservoir ecology, immunopathogenesis, diagnosis, treatment safety and sustainable control. Recent national data documented 13,625 cutaneous leishmaniasis cases reported in Libyan hospitals during 2019–2022, with pronounced spatial and seasonal heterogeneity; a 2024–2025 study from Al-Khums further demonstrates that active transmission persists in contemporary urban and peri-urban contexts. Molecular evidence confirms circulation of both *Leishmania major* and *Leishmania tropica*, while major gaps remain in current species-resolved surveillance, visceral leishmaniasis burden estimation, sand-fly monitoring and reservoir attribution. The available evidence therefore argues against viewing leishmaniasis as an isolated dermatological problem. Instead, Libya illustrates how a neglected tropical disease can be sustained by interactions among ecological suitability, human vulnerability, animal reservoirs, vector ecology and fragmented surveillance. Antimonial treatment remains relevant but requires stronger pharmacovigilance, biochemical and haematological monitoring, and access to safer, context-appropriate alternatives. A national response should integrate geocoded human surveillance, reference molecular diagnostics, entomological and reservoir monitoring, climate-informed risk mapping, treatment-safety registries, community engagement and intersectoral governance. Aligning these actions with the WHO neglected tropical disease road map and Sustainable Development Goals 3, 6, 11, 13 and 17 would transform leishmaniasis control from episodic case management into a measurable programme of health-system, environmental and climate resilience. Libya should be regarded not as a peripheral endemic setting, but as a sentinel context for understanding how neglected diseases persist when ecological opportunity and institutional vulnerability converge.

Keywords: leishmaniasis; Libya; One Health; cutaneous leishmaniasis; neglected tropical diseases; climate change; sand flies; zoonoses; pharmacovigilance; Sustainable Development Goals

1. Introduction

Leishmaniasis is a group of vector-borne neglected tropical diseases caused by intracellular protozoa of the genus *Leishmania* and transmitted predominantly by infected female phlebotomine sand flies. Clinical expression ranges from localised cutaneous lesions to mucosal disease and potentially fatal visceral infection. Although the global distribution is broad, disease burden is concentrated in eco-epidemiological foci in which poverty, housing conditions, migration, malnutrition, vector exposure, animal reservoirs and health-system access interact. The World Health Organization (WHO) continues to identify North Africa as one of the four principal global eco-epidemiological areas in which leishmaniasis remains a major health problem (WHO, 2025).

Neglect is expressed not only through the scarcity of new drugs and vaccines, but also through weak surveillance visibility. A disease can remain biologically persistent while appearing administratively small when cases are underdiagnosed, laboratory confirmation is limited, reporting systems are fragmented or transmission occurs in populations with constrained access to care. This distinction is particularly important in Libya, where recent national data and local studies demonstrate substantial cutaneous leishmaniasis (CL) activity despite major gaps in species-level diagnosis, vector surveillance and integrated human–animal–environment monitoring (Saad et al., 2025; Juwaid et al., 2025).

Libya combines ecological conditions favourable to zoonotic cutaneous leishmaniasis (ZCL) with vulnerabilities that can increase exposure or reduce the effectiveness of control. Arid and semi-arid landscapes, wadis, rodent habitats, peri-urban expansion and agricultural interfaces provide ecological opportunities for vector–reservoir contact. At the same time, population displacement and the consequences of prolonged conflict may disrupt surveillance, laboratory services, municipal functions and continuity of vector-control programmes. Systematic evidence from conflict-affected settings shows that infectious-disease risk is amplified through displacement, infrastructure damage, disrupted health services and weakened surveillance, although the magnitude and direction of effects are context specific (Marou et al., 2024).

A One Health framing is therefore not optional rhetoric for leishmaniasis in Libya; it is a practical epidemiological requirement. Transmission occurs at a human–animal–environment interface, and sustainable control depends on clinical services, veterinary and wildlife knowledge, entomology, environmental

management, climate information and governance. This approach is consistent with the WHO neglected tropical disease (NTD) road map and its One Health companion framework, which call for country ownership, cross-sectoral action and measurable links to sustainable development (WHO, 2021; WHO, 2022). Recent Libyan analyses of One Health capacity further show that relevant institutions exist but coordination remains functionally siloed, reinforcing the need to translate networks into routine joint surveillance and response (Miller et al., 2023; Saidouni et al., 2025).

This review critically re-examines leishmaniasis in Libya through five linked questions: what the contemporary epidemiological evidence shows; what is known—and still unknown—about parasite, vector and reservoir ecology; how host immunobiology and diagnostic capacity shape clinical outcomes; whether current treatment practices are matched by adequate safety monitoring; and how a climate-resilient One Health strategy can convert fragmented evidence into sustained national control. The objective is not to portray Libya as an exceptional case, but to use it as a sentinel setting for the broader global problem of NTD persistence under simultaneous ecological and institutional pressures.

2. Evidence scope and critical review approach

This article is a critical narrative review rather than a formal systematic review or meta-analysis. Evidence was prioritised from peer-reviewed literature indexed in major biomedical databases and publisher platforms, together with WHO technical and surveillance documents. Contemporary evidence from 2020 to August 2026 was prioritised; older Libyan studies were retained only when they provided unique molecular, ecological or treatment information not replaced by newer work.

Reference selection favoured sources with verifiable digital object identifiers (DOIs), transparent methods and direct relevance to Libya, North Africa or leishmaniasis control. National and local Libyan evidence was interpreted alongside regional and global studies to avoid over-extrapolating from single-centre observations. Because the Libyan evidence base remains heterogeneous, distinctions are made throughout between documented findings, plausible regional inference and unresolved national research needs. This is essential for a policy-oriented review: an evidence gap should not be converted into an epidemiological claim merely because a mechanism is biologically plausible.

3. Contemporary epidemiology: persistent burden, spatial heterogeneity and surveillance blind spots

The strongest recent national evidence comes from a retrospective analysis of Libyan hospital data for 2019–2022. A cumulative 13,625 CL cases were reported, including 6,712 cases in 2019, 3,336 in 2020, 2,174 in 2021 and 1,403 in 2022. The corresponding reported incidence fell from 111 per 100,000 population in 2019 to 20 per 100,000 in 2022. Cases displayed marked seasonality, with high proportions in the colder months, and were reported across multiple western municipalities. This pattern is better described as a high but fluctuating burden than as a simple uninterrupted rise (Saad et al., 2025).

The same national analysis reported 57.6% of cases in males and identified the 10–19-year age group as the most represented, with substantial involvement of school-aged populations. Such distributions may reflect outdoor exposure, behaviour, occupation, care-seeking and demographic structure rather than biological susceptibility alone. Importantly, the study reported no locally acquired cases from the eastern region during the analysed period; this should not be interpreted as proof of ecological absence because surveillance coverage, travel histories, referral patterns and diagnostic access can shape observed maps (Saad et al., 2025).

More recent local data indicate continuing transmission. In Al-Khums, 802 confirmed CL cases were analysed during 2024–2025, with spatial clustering in defined localities and seasonal peaks that reinforce the value of

high-resolution municipal surveillance (Juwaid et al., 2025). Local studies of this type are particularly useful when they are integrated into national reporting because they can reveal micro-hotspots that are diluted in national aggregates. Comparable persistence in Algeria further supports viewing Libyan CL within a connected Maghreb ecological context rather than as an isolated national phenomenon (Messaoudene et al., 2023).

Molecular evidence remains older but epidemiologically important. In a 2011–2012 Libyan series, successful molecular characterisation of 81 samples identified *Leishmania major* in 72.8% and *Leishmania tropica* in 27.2%, demonstrating that species diversity is relevant to clinical and control decisions (Amro et al., 2017). Ecological niche modelling likewise identified structured overlap among ZCL cases, vectors and reservoir distributions in Libya (Samy et al., 2016). These studies remain valuable because no recent national molecular atlas has superseded them.

The epidemiological priority for 2026–2030 is therefore not simply to count more cases, but to improve the denominator and the biological resolution of surveillance. Libya needs geocoded, laboratory-linked case data that distinguish probable from confirmed disease, capture travel and displacement history, record lesion number and site, and connect a subset of human cases to parasite species, vector collections and reservoir observations. Without these elements, apparent declines may reflect true control, reduced access, changes in reporting or some combination of these processes.

Table 1. Evidence-to-action map for leishmaniasis in Libya

Domain	What current evidence supports	Critical uncertainty	Priority action (2026–2030)
Human burden	13,625 reported CL cases in 2019–2022; continued local transmission documented in Al-Khums in 2024–2025.	Completeness of reporting; burden outside routinely reporting facilities; current VL burden.	National case registry with geocoding, unique episode identifiers, laboratory status and travel/displacement history.
Parasite diversity	<i>Leishmania major</i> and <i>Leishmania tropica</i> have been molecularly identified in Libya.	Current species proportions; possible geographic shifts; contemporary <i>L. infantum</i> evidence.	Sentinel PCR/speciation and genotyping linked to clinical and ecological metadata.
Vector ecology	<i>Phlebotomus papatasi</i> is epidemiologically important for ZCL and ecological suitability has been modelled.	Current sand-fly species composition, abundance, seasonality and insecticide susceptibility.	Standardised seasonal trapping network and insecticide-resistance monitoring.
Reservoirs	Rodent-associated ZCL ecology is strongly plausible and historically supported.	Contemporary infection prevalence and reservoir competence by locality.	Targeted rodent/reservoir studies using molecular confirmation; avoid indiscriminate control.
Treatment	Cryotherapy and	Comparative outcomes,	Prospective treatment registry with

	intralesional/systemic antimonials remain prominent in practice.	adverse events, relapse and adherence in routine Libyan care.	outcome and safety endpoints.
Governance	One Health institutions and networks exist in Libya.	Routine data sharing and operational accountability across sectors.	Formal national One Health leishmaniasis working group with shared indicators and response triggers.

4. Parasite–vector–reservoir ecology: the One Health core of transmission

ZCL in Libya is most strongly associated with *Leishmania major*, the sand fly *Phlebotomus papatasi* and rodent-associated transmission systems. *Psammomys obesus* and *Meriones shawi* have long been epidemiologically relevant in North African ZCL ecology, and Libyan ecological modelling supports the principle that human risk emerges from spatial overlap between the parasite, vector and suitable reservoir habitats (Samy et al., 2016). The broader zoonotic literature also shows that *Leishmania* infections occur across diverse wild mammalian hosts, highlighting the need to distinguish infection from true reservoir competence before assigning control targets (Azami-Conesa et al., 2021).

The practical implication is that reservoir control must be evidence based. Burrow destruction or indiscriminate rodent killing can alter local ecology without necessarily interrupting transmission and may generate unintended environmental effects. Experimental field work in another *Leishmania major*–*Psammomys obesus*–*Phlebotomus papatasi* system demonstrates that targeted interruption of the reservoir-to-vector transmission pathway can be effective, but the intervention logic depends on detailed knowledge of the local cycle (Tsurim et al., 2023). Libya therefore needs locality-specific reservoir mapping before operational control is scaled.

Visceral leishmaniasis (VL) requires particular caution in interpretation. *Leishmania infantum* is the major zoonotic VL agent in the Mediterranean, where dogs are central reservoirs in many settings. However, contemporary species-resolved Libyan data are sparse. The appropriate conclusion is not that canine transmission is absent or definitively established nationwide, but that current evidence is insufficient. A focused VL surveillance programme should combine paediatric and immunocompromised clinical vigilance with canine serological/molecular surveys and sand-fly identification in historically or clinically suspicious foci (Cosma et al., 2024).

Environmental risk is also dynamic. Sand flies exploit microhabitats rather than administrative boundaries. Cracks, animal shelters, rodent burrows, unmanaged

organic waste and peri-domestic resting sites can create fine-scale exposure opportunities. Urban expansion into semi-natural areas may therefore increase contact with established transmission cycles even when the urban core itself is not a classical sand-fly habitat. This is why municipal planning, waste management and housing improvement belong within disease prevention rather than outside it.

5. Climate change, urbanisation, mobility and conflict: interacting risk multipliers

Climate change should be incorporated into leishmaniasis planning without being used as a catch-all explanation for every fluctuation in case numbers. Temperature, rainfall, humidity and vegetation can influence sand-fly survival, activity windows and reservoir ecology, but observed disease remains the product of ecological suitability, human exposure, surveillance and control. A 2025 Maghreb modelling study projected shifts in CL risk under climate scenarios and supported the integration of climate information into regional surveillance (Saadene and Salhi, 2025). Ecological niche modelling in Morocco similarly projected climate-sensitive changes in the suitability of *Phlebotomus papatasi* and key reservoir species, providing a mechanistic regional warning relevant to North African planning (Daoudi et al., 2025). For Libya, the immediate research need is not to import another country's risk map, but to build a national climate–vector–case dataset. Meteorological variables should be linked to repeated sand-fly collections and geocoded human cases, allowing lagged relationships and local thresholds to be estimated. A climate-informed early-warning system should only be operationalised after prospective validation against observed vector abundance and case incidence.

Conflict and displacement can magnify transmission risk through several pathways: movement of susceptible populations into endemic areas, movement of infected people into areas with competent vectors, disrupted waste and housing services, reduced access to diagnosis, and interruption of surveillance or vector control. A recent systematic review across conflict settings identified these pathways as recurrent drivers of infectious-disease

vulnerability (Marou et al., 2024). In Libya, national One Health assessments have separately documented constraints in laboratory capacity, sustained prevention programmes and intersectoral communication, providing a context-specific institutional explanation for why ecological risk may become harder to manage (Miller et al., 2023).

These factors should be treated as interacting risk multipliers rather than independent causes. Climate suitability does not inevitably produce an outbreak; displacement does not inevitably introduce disease; and conflict does not uniformly increase incidence. The public-health risk emerges when ecological opportunity, exposure and weakened detection/control occur together. This interaction is precisely where a One Health and resilience framework adds analytical value.

6. Immunopathogenesis: from macrophage infection to clinical heterogeneity

Leishmania parasites are obligate intracellular organisms that establish infection principally within mononuclear phagocytes. Following inoculation, promastigotes are internalised by macrophages and other phagocytic cells and transform into amastigotes adapted to the phagolysosomal environment. Disease outcome is determined not by a binary protective/non-protective response, but by the balance between parasite persistence, macrophage activation, antigen presentation, T-cell polarisation and the intensity of local inflammation (Almeida et al., 2023).

Protective control of many *Leishmania* infections is associated with IL-12-driven cellular responses, IFN- γ production and activation of macrophage leishmanicidal mechanisms. Yet excessive or dysregulated inflammation can itself contribute to tissue damage. In North African CL, clinical heterogeneity reflects both parasite species and host immune phenotype, making simple Th1-versus-Th2 descriptions insufficient for translational interpretation (Saidi et al., 2023).

For Libya, immunological research should be linked to clinical phenotypes rather than conducted in isolation. Prospective studies could compare immune markers with parasite species, lesion number, lesion duration, treatment response, relapse and scar outcomes. Such work would strengthen the bridge between basic parasitology and patient-centred care and could support future vaccine or immunodiagnostic research. However, immune biomarkers should not be presented as ready for routine implementation until validated against clinically meaningful outcomes in local populations.

7. Diagnosis: microscopy remains essential, but species-resolved surveillance is the strategic gap

In many endemic settings, CL diagnosis combines clinical assessment with direct microscopy of lesion material. Microscopy is relatively inexpensive, rapidly deployable and particularly valuable when amastigotes are abundant, but sensitivity depends on lesion age, sampling technique, smear quality, staining and operator expertise. Culture and histopathology can provide additional information, while molecular assays substantially improve species identification and can support difficult or atypical cases (Piyasiri et al., 2023).

Recent Libyan national data indicate that lesion characteristics and epidemiological information remain central to clinical diagnosis, with Giemsa-stained microscopy used for laboratory confirmation (Saad et al., 2025). This is a reasonable core diagnostic platform, but it cannot by itself deliver the species-resolution required for modern epidemiological surveillance. Species matters because ecology, reservoir relationships, natural history and treatment response can differ.

A realistic national model is tiered rather than universally molecular. Peripheral laboratories should be strengthened for high-quality microscopy, specimen collection and reporting; regional laboratories should offer confirmatory testing for complicated, recurrent or atypical disease; and a national reference network should undertake PCR/speciation and periodically genotype representative isolates. Digital microscopy and external quality assurance could improve standardisation without requiring every facility to become a molecular laboratory. The most consequential diagnostic gap may be VL. Fever, splenomegaly, cytopenias and systemic illness are non-specific, and delayed diagnosis carries substantial risk. Libya therefore needs explicit referral and diagnostic algorithms for suspected VL, especially in children, immunocompromised patients and individuals with relevant epidemiological exposure. The goal is not to assume a high VL burden, but to ensure that a severe form of disease is not missed because routine surveillance is overwhelmingly oriented towards visible skin lesions.

8. Treatment and pharmacovigilance: moving from drug availability to treatment safety

CL treatment is complicated by species-specific efficacy, lesion characteristics, host factors, toxicity, cost, route of administration and the possibility of spontaneous healing. Contemporary drug-development reviews emphasise that the therapeutic pipeline remains limited relative to the global burden and that treatment failure can result from

Leishmaniasis in Libya at the Human–Animal–Environment Interface

parasite susceptibility, host immunity, pharmacokinetics, adherence and operational factors rather than resistance alone (Corman et al., 2023; Wijnant et al., 2022; Santos et al., 2023).

In Libya, current practice includes cryotherapy, intralesional antimonials and systemic antimonials. National 2019–2022 data reported liquid nitrogen as the most frequently recorded treatment, followed by intralesional meglumine antimoniate and intralesional sodium stibogluconate; importantly, treatment information was absent for a substantial proportion of records (Saad et al., 2025). Earlier Libyan treatment evaluation also documented the central role of Pentostam in local CL management (Elammari et al., 2017). The policy message is not that one modality should replace all others, but that treatment choice should be standardised by lesion complexity, species where known, contraindications, pregnancy status, age, immune status and availability.

Pentavalent antimonials remain clinically important but their safety profile justifies structured monitoring. Libyan experimental studies reported dose-associated biochemical/haematological abnormalities and histopathological liver and kidney injury following Pentostam exposure in mice (Elammari et al., 2022; Sariti and Elammari, 2021). These preclinical findings should not be used to quantify human risk directly, but they are

concordant with the wider clinical rationale for renal, hepatic, pancreatic and cardiac safety assessment during systemic antimonial therapy. In routine programmes, pharmacovigilance should be treated as part of treatment effectiveness rather than as an optional add-on.

Alternative approaches require the same evidence discipline. Miltefosine offers oral administration but has important tolerability and reproductive-safety considerations, and local amphotericin B approaches remain promising but supported by heterogeneous clinical evidence (Astman et al., 2024; Alves et al., 2024). Sodium stibogluconate-based regimens can also impose substantial treatment burden in routine care (van Henten et al., 2023). Therefore, Libya should prioritise access to multiple evidence-based modalities, specialist referral for complex disease and prospective collection of treatment outcomes rather than adopting a single-drug solution.

A national treatment-safety registry would be a high-value intervention. Minimum variables should include species if available, lesion characteristics, drug and route, dose, baseline renal/hepatic profile, electrocardiographic assessment when indicated, adverse events, completion, clinical cure, relapse and scarring. Aggregated outcomes could then inform national guidelines and procurement decisions using local effectiveness and safety data rather than historical habit alone.

Table 2. Diagnostic and therapeutic priorities for a tiered Libyan leishmaniasis programme

Level	Core capability	When to escalate	Quality/safety indicator
Primary/peripheral care	Clinical recognition; lesion documentation; appropriate smear collection; wound care; referral criteria.	Atypical lesion, mucosal involvement, severe/disseminated disease, immunocompromise, treatment failure.	Proportion of suspected cases sampled correctly; referral completion.
District/regional laboratory	High-quality Giemsa microscopy; histopathology access; specimen preservation and transport.	Microscopy-negative high-suspicion cases; recurrent disease; outbreak investigation.	Microscopy EQA concordance; turnaround time; specimen rejection rate.
National/reference laboratory	PCR/speciation; genotyping on sentinel samples; complex case support; biobanking.	Unusual epidemiology, severe disease, suspected new focus, research/surveillance sampling.	Percentage of sentinel isolates speciated; QA proficiency; data linkage to registry.
Treatment service	Local therapies for appropriate uncomplicated CL; systemic treatment when indicated; standardised follow-up.	Systemic toxicity, pregnancy, paediatric complexity, relapse, suspected VL.	Cure/relapse; adverse-event rate; completion; baseline/follow-up safety tests.
Pharmacovigilance	Standard adverse-event reporting and treatment-safety registry.	Serious adverse event or signal above expected frequency.	Completeness of adverse-event reporting and action on safety signals.

9. Neglect beyond incidence: scarring, stigma, economic burden and health equity

Case counts alone underestimate the burden of CL. Lesions can be painful, prolonged and disfiguring; scars may be

permanent; facial lesions can affect self-image and social interaction; repeated clinic visits and treatment courses can impose transport and productivity costs. A broad review of leishmaniasis vulnerabilities identified poverty, housing, migration, conflict and limited access to care as interacting drivers of both infection and socioeconomic harm (Grifferty et al., 2021).

The Libyan age distribution reported in recent national data makes this especially relevant for children and adolescents. When disease affects visible sites during school years, the consequences may extend to stigma, absenteeism and psychosocial well-being. These outcomes are rarely captured in routine leishmaniasis surveillance. Incorporating patient-reported outcomes, scar assessment and school/work disruption into selected sentinel studies would make the burden visible in terms that are meaningful to families and policymakers, not only parasitologists.

Equity also requires attention to displaced people, migrants and communities distant from specialist dermatology or parasitology services. Surveillance systems should record access barriers and nationality without allowing these variables to become proxies for blame. The epidemiological purpose is to identify where prevention and care are failing, not to attribute transmission to vulnerable populations.

10. From concept to implementation: a One Health and Sustainable Development framework for Libya

WHO's NTD road map for 2021–2030 explicitly connects disease control with country ownership, cross-cutting approaches and the Sustainable Development Goals, while the One Health companion framework calls for

integrated action across sectors (WHO, 2021; WHO, 2022). *Leishmaniasis* is a strong test case for this agenda because its transmission cannot be sustainably controlled by the health sector alone.

Recent work in Libya provides an unusually timely governance opportunity. A 2023 One Health assessment identified gaps in laboratory capacity, disease-control continuity and communication between sectors in the context of prolonged instability (Miller et al., 2023). A subsequent national stakeholder-network analysis found a structurally connected but functionally siloed One Health landscape, with public-health, animal-health, environmental, agricultural and regulatory institutions clustered rather than routinely integrated (Saidouni et al., 2025). *Leishmaniasis* can serve as a practical demonstration programme through which these institutional relationships become operational rather than aspirational.

The Sustainable Development Goal (SDG) link should be defined through measurable co-benefits. SDG 3 is advanced by earlier diagnosis, safer treatment and reduced NTD burden. SDG 6 is relevant where sanitation and waste management reduce peri-domestic habitats and improve environmental health. SDG 11 is operationalised through healthier settlements, housing and municipal services. SDG 13 is addressed through climate-informed vector surveillance and adaptation. SDG 17 is essential because no single institution can maintain human, vector, reservoir, environmental and climate datasets alone.

This framing also prevents a common weakness in NTD manuscripts: adding the SDGs as a decorative final paragraph. In a Q1-level policy review, sustainable development should change the proposed intervention architecture, indicators and accountability. For leishmaniasis in Libya, the SDGs are useful precisely because they force the programme to measure benefits beyond clinical cure.

Table 3. Leishmaniasis control as an SDG co-benefit programme

SDG	Leishmaniasis action	Co-benefit	Illustrative indicator
SDG 3 — Good Health and Well-being	Earlier diagnosis, standardised treatment, pharmacovigilance, VL referral.	Reduced morbidity, scarring and preventable treatment toxicity.	Diagnostic delay; confirmed-case proportion; cure/relapse; serious adverse events.
SDG 6 — Clean Water and Sanitation	Improved waste and environmental sanitation around high-risk settlements.	Reduced peri-domestic vector/reservoir habitat and broader environmental-health gains.	Waste-service coverage in mapped hotspots; environmental risk score.
SDG 11 — Sustainable Cities	Risk-sensitive housing, settlement planning and	Reduced exposure at urban–peri-urban ecological interfaces.	Hotspot households receiving environmental

and Communities	community protection.		risk reduction; housing-risk audit.
SDG 13 — Climate Action	Climate-linked sand-fly surveillance and validated early warning.	Climate-resilient vector-borne disease preparedness.	Forecast accuracy; lead time before seasonal peaks; response activation.
SDG 17 — Partnerships for the Goals	Routine NCDC–animal health–environment–municipal–academic data sharing.	Institutionalised One Health governance.	Joint dashboard completeness; multisectoral reviews; actions closed on time.

11. A climate-resilient national control architecture

The proposed national architecture is intentionally modular. It can begin with sentinel sites in high-burden municipalities and expand as data quality improves. Six components should be implemented as a connected system:

- Integrated human surveillance: adopt a standard electronic case definition, record laboratory status, geocode residence/exposure when ethically appropriate, and distinguish local acquisition from travel-associated disease.
- Entomological surveillance: establish repeated seasonal sand-fly trapping in representative ecological strata, identify species, record abundance and progressively incorporate insecticide-susceptibility monitoring. WHO's operational manual provides a practical framework for strengthening sand-fly surveillance and evaluating vector-control interventions (WHO, 2023).
- Reservoir surveillance: conduct targeted molecular surveys of plausible rodent and canine hosts in defined foci, with explicit criteria for reservoir competence and ecological risk before control measures are recommended.
- Reference laboratory network: strengthen microscopy at peripheral level while creating dependable PCR/speciation pathways, quality assurance and biobanking at regional/national level.
- Clinical governance and pharmacovigilance: standardise treatment algorithms, baseline safety assessment, adverse-event reporting, outcome follow-up and referral for complex CL or suspected VL.
- Climate and municipal integration: overlay validated case/vector information with meteorological and environmental indicators, then use the resulting maps to target waste management, housing risk reduction, communication and seasonal preparedness rather than relying on blanket interventions.

Community engagement should sit across all six components. Bed nets and personal protection can be useful, but messaging must reflect sand-fly biting

behaviour, local housing patterns and what households can realistically do. Communication should explain where and when risk is highest, when lesions require assessment, why completing treatment and follow-up matters, and why reservoir or insecticide interventions may be targeted rather than universal. Community participation is more likely to be sustained when it is linked to visible municipal improvements rather than delivered as one-way health education.

12. Research gaps and a 2026–2030 priority agenda

The most important gap in Libyan leishmaniasis research is not the absence of individual studies; it is the absence of a longitudinal, interoperable evidence system. Epidemiological studies, molecular work, vector ecology and treatment research currently answer different questions with limited linkage between datasets. A Q1-level research agenda should therefore prioritise studies that connect these domains.

First, a national molecular epidemiology programme should update the distribution of *Leishmania major*, *Leishmania tropica* and any other circulating species using representative sampling rather than convenience collections alone. Second, longitudinal entomological studies should quantify sand-fly seasonality and species composition across ecological zones. Third, reservoir studies should combine infection detection with ecological evidence of host–vector contact. Fourth, prospective treatment cohorts should compare routine effectiveness, toxicity, relapse and scarring across modalities. Fifth, climate-health models should be locally validated before being used as early-warning tools. Sixth, implementation research should measure whether One Health data sharing actually shortens detection-to-response time.

Vaccine research remains a longer-term strategic opportunity. The global vaccine value profile for leishmaniasis highlights continuing public-health and societal value in vaccine development despite scientific and implementation challenges (Kaye et al., 2023). Libya can contribute meaningfully to this field through well-

characterised parasite isolates, clinical phenotyping and immunological cohorts, even if vaccine trials are not an immediate national priority.

Finally, research evaluation should move beyond publication counts. Useful national metrics include the proportion of cases with laboratory confirmation, the proportion of sentinel isolates with species identification, the number of municipalities with validated vector-seasonality data, the completeness of treatment-safety monitoring and the time from hotspot detection to multisectoral response. These indicators turn research capacity into control capacity.

13. Strategic recommendations

1. Institutionalise a national One Health leishmaniasis platform with defined ownership, data-sharing rules, quarterly review and joint response thresholds across human health, animal health, environment, municipal services and academia.
2. Build a tiered diagnostic network in which microscopy is strengthened rather than displaced, while PCR/speciation becomes routinely available for sentinel surveillance, severe/atypical cases, treatment failure and outbreak investigation.
3. Create an integrated geospatial surveillance system linking human cases with repeated sand-fly collections, reservoir observations and environmental/climate variables, with safeguards for privacy and responsible use of location data.
4. Establish a treatment and pharmacovigilance registry that captures drug, route, dose, baseline safety tests, adverse events, cure, relapse and scar outcomes; use these data to revise national protocols and procurement.
5. Prioritise municipal environmental management in evidence-defined hotspots, including waste services and peri-domestic risk reduction, while avoiding indiscriminate reservoir destruction or insecticide use without ecological and susceptibility evidence.
6. Invest in community-centred risk communication that addresses school-aged populations, displaced communities and high-exposure households, and measure behavioural and service-access outcomes rather than counting educational sessions alone.
7. Use leishmaniasis as a demonstration programme for Libya's wider One Health institutionalisation. A functioning joint platform for this NTD would create reusable surveillance, laboratory and governance capacity for other zoonotic and climate-sensitive diseases.

14. Limitations of the current evidence base

The principal limitation of this review is the limitation of the evidence it synthesises. Recent Libyan national surveillance data are valuable but remain dependent on facility reporting and do not provide complete species resolution. Local studies can identify hotspots but may not be nationally generalisable. Some foundational ecological and molecular studies are older because newer national equivalents are not yet available. Evidence on contemporary VL incidence, canine infection, reservoir competence, sand-fly abundance and insecticide susceptibility is especially sparse.

Accordingly, this review deliberately avoids inferring absence from non-reporting and avoids treating regional climate or reservoir findings as direct measurements of Libyan transmission. These limitations strengthen rather than weaken the central argument: sustainable control requires an integrated system capable of converting uncertainty into testable surveillance questions.

15. Conclusion

Leishmaniasis in Libya is a persistent neglected tropical disease whose significance extends beyond the skin lesion. Recent national and local evidence confirms substantial and continuing CL transmission, while older molecular and ecological work shows that the biological system is more complex than a single-species, single-vector narrative. At the same time, major uncertainties remain in current parasite distribution, vector ecology, reservoir competence, VL burden and treatment outcomes.

The most important policy shift is therefore conceptual and operational: from reactive treatment of visible lesions to management of the transmission system. That means linking human surveillance to entomology, animal/reservoir evidence, environmental services, climate information, laboratory quality and pharmacovigilance. It also means measuring success through reduced diagnostic delay, safer treatment, fewer hotspots, stronger municipal environments and faster multisectoral response—not only through annual case counts.

Libya can contribute a wider message to the global NTD agenda. The country demonstrates how leishmaniasis can remain entrenched where ecological suitability overlaps with mobility, climate pressure and health-system fragmentation. In such settings, the greatest threat is not transmission alone, but invisibility: cases that are not biologically characterised, vectors that are not monitored, adverse events that are not recorded and sectors that do not share data. A climate-resilient One Health programme

aligned with the Sustainable Development Goals would convert that invisibility into actionable evidence. For a

neglected disease, visibility is the first condition of control.

References

- Almeida, F.S., Vanderley, S.E.R., Comberlang, F.C., de Andrade, A.G., Cavalcante-Silva, L.H.A., Silva, E.S., Palmeira, P.H.S., do Amaral, I.P.G. and Keesen, T.S.L. (2023) ‘*Leishmaniasis*: immune cells crosstalk in macrophage polarization’, *Tropical Medicine and Infectious Disease*, 8(5), 276. <https://doi.org/10.3390/tropicalmed8050276>
- Alves, L.L., Freire, M.L., Troian, I.L., Morais-Teixeira, E. and Cota, G. (2024) ‘Local amphotericin B therapy for cutaneous leishmaniasis: a systematic review’, *PLOS Neglected Tropical Diseases*, 18(4), e0012127. <https://doi.org/10.1371/journal.pntd.0012127>
- Amro, A., Al-Dwibe, H., Gashout, A., Moskalenko, O., Galafin, M., Hamarsheh, O., Frohme, M., Jaeschke, A., Schönan, G. and Kuhls, K. (2017) ‘Spatiotemporal and molecular epidemiology of cutaneous leishmaniasis in Libya’, *PLOS Neglected Tropical Diseases*, 11(9), e0005873. <https://doi.org/10.1371/journal.pntd.0005873>
- Astman, N., Arbel, C., Katz, O., Barzilai, A., Solomon, M. and Schwartz, E. (2024) ‘Tolerability and safety of miltefosine for the treatment of cutaneous leishmaniasis’, *Tropical Medicine and Infectious Disease*, 9(9), 218. <https://doi.org/10.3390/tropicalmed9090218>
- Azami-Conesa, I., Gómez-Muñoz, M.T. and Martínez-Díaz, R.A. (2021) ‘A systematic review (1990–2021) of wild animals infected with zoonotic *Leishmania*’, *Microorganisms*, 9(5), 1101. <https://doi.org/10.3390/microorganisms9051101>
- Corman, H.N., McNamara, C.W. and Bakowski, M.A. (2023) ‘Drug discovery for cutaneous leishmaniasis: a review of developments in the past 15 years’, *Microorganisms*, 11(12), 2845. <https://doi.org/10.3390/microorganisms11122845>
- Cosma, C., Maia, C., Khan, N., Infantino, M. and Del Riccio, M. (2024) ‘*Leishmaniasis* in humans and animals: a One Health approach for surveillance, prevention and control in a changing world’, *Tropical Medicine and Infectious Disease*, 9(11), 258. <https://doi.org/10.3390/tropicalmed9110258>
- Daoudi, M., Outammassine, A., Olivier, D., Amane, M., Beaulieu, M., Akarid, A., Ndao, M., Hafidi, M., Boussaa, S. and Boumezzough, A. (2025) ‘Modeling the impact of climate change for the potential distribution of the main vector and reservoirs of zoonotic cutaneous leishmaniasis due to *Leishmania major* in Morocco’, *Frontiers in Tropical Diseases*, 6, 1629454. <https://doi.org/10.3389/fitd.2025.1629454>
- Elammari, N.E., Sariti, S.R., Elhadar, J.M.S. and Asteal, F.A.A. (2017) ‘Evaluation of the cutaneous leishmaniasis treatment in Al-Mergheb, Libya’, *Journal of Academic Research*, 8, pp. 294–308. <https://doi.org/10.65540/jar.v8i.1191>
- Elammari, N.E., Busaadia, M.A.S., Sulaiman, Y., Al Abbar, M.Y. and Omar, G.O. (2022) ‘Biochemical and hematological evaluation pattern of Pentostam-induced hepatotoxicity and nephrotoxicity in albino mice’, *Journal of Pharmaceutical Negative Results*, 13(Special Issue 5), pp. 460–465. <https://doi.org/10.47750/pnr.2022.13.S05.74>
- Grifferty, G., Shirley, H., McGloin, J., Kahn, J., Orriols, A. and Wamai, R. (2021) ‘Vulnerabilities to and the socioeconomic and psychosocial impacts of the leishmaniasis: a review’, *Research and Reports in Tropical Medicine*, 12, pp. 135–151. <https://doi.org/10.2147/RRTM.S278138>
- Juwaid, S.E., Takala, F., Kahbar, F., Dokhan, M.R. and Elammari, N.E. (2025) ‘Epidemiological pattern of cutaneous leishmaniasis in Al-Khums City, Libya: a descriptive study (2024–2025)’, *Journal of Academic Research*, 29(2), pp. 44–51. <https://doi.org/10.65540/jar.v29i2.1325>
- Kaye, P.M., Matlashewski, G., Mohan, S., Le Rutte, E., Mondal, D., Khamesipour, A. and Malvolti, S. (2023) ‘Vaccine value profile for leishmaniasis’, *Vaccine*, 41(Suppl. 2), pp. S153–S175. <https://doi.org/10.1016/j.vaccine.2023.01.057>
- Marou, V., Vardavas, C.I., Aslanoglou, K., Nikitara, K., Plyta, Z., Leonardi-Bee, J., Atkins, K., Condell, O., Lamb, F. and Suk, J.E. (2024) ‘The impact of conflict on infectious disease: a systematic literature review’, *Conflict and Health*, 18, 27. <https://doi.org/10.1186/s13031-023-00568-z>
- Messaoudene, F., Boukraa, S., Boubidi, S.C., Guerzou, A. and Ouahabi, A. (2023) ‘Human cutaneous leishmaniasis in North Africa and its threats to public health: a statistical study focused on Djelfa (Algeria)’, *Microorganisms*, 11(10), 2608. <https://doi.org/10.3390/microorganisms11102608>
- Miller, L.N., Elmselati, H., Fogarty, A.S., Farhat, M.E., Standley, C.J., Abuabaid, H.M., Zorgani, A., Elahmer, O. and Sorrell, E.M. (2023) ‘Using One

- Health assessments to leverage endemic disease frameworks for emerging zoonotic disease threats in Libya', PLOS Global Public Health, 3(7), e0002005.
<https://doi.org/10.1371/journal.pgph.0002005>
- Piyasiri, S.B., Dewasurendra, R., Samaranayake, N. and Karunaweera, N. (2023) 'Diagnostic tools for cutaneous leishmaniasis caused by *Leishmania donovani*: a narrative review', Diagnostics, 13(18), 2989. <https://doi.org/10.3390/diagnostics13182989>
- Saad, K.A., Ageehal, H.A., Elgrari, A.S. and Ammar, S.A. (2025) 'The burden of cutaneous leishmaniasis in Libya (2019–2022): epidemiological insights and treatment practices', Open Veterinary Journal, 15(4), pp. 1685–1694.
<https://doi.org/10.5455/OVJ.2025.v15.i4.20>
- Saadene, Y. and Salhi, A. (2025) 'Spatio-temporal modeling of cutaneous leishmaniasis under climate change scenarios in the Maghreb region (2021–2100)', Acta Tropica, 263, 107548.
<https://doi.org/10.1016/j.actatropica.2025.107548>
- Saidi, N., Blaizot, R., Prévot, G., Aoun, K., Demar, M., Cazenave, P.A., Bouratbine, A. and Pied, S. (2023) 'Clinical and immunological spectra of human cutaneous leishmaniasis in North Africa and French Guiana', Frontiers in Immunology, 14, 1134020.
<https://doi.org/10.3389/fimmu.2023.1134020>
- Saidouni, A., Ghazy, R.M., Zorgani, A., Elahmer, O., Natuh, D., Osman, R.M., El Halafi, A. and Zouiten, A. (2025) 'Toward One Health institutionalization: harnessing stakeholder network as leverage to strengthen health security in Libya', Frontiers in Public Health, 13, 1651901.
<https://doi.org/10.3389/fpubh.2025.1651901>
- Samy, A.M., Annajar, B.B., Dokhan, M.R., Boussaa, S. and Peterson, A.T. (2016) 'Coarse-resolution ecology of etiological agent, vector, and reservoirs of zoonotic cutaneous leishmaniasis in Libya', PLOS Neglected Tropical Diseases, 10(2), e0004381.
<https://doi.org/10.1371/journal.pntd.0004381>
- Santos, G.A., Sousa, J.M., Aguiar, A.H.B.M., Torres, K.C.S., Coelho, A.J.S., Ferreira, A.L. and Lima, M.I.S. (2023) 'Systematic review of treatment failure and clinical relapses in leishmaniasis from a multifactorial perspective: clinical aspects, factors associated with the parasite and host', Tropical Medicine and Infectious Disease, 8(9), 430.
<https://doi.org/10.3390/tropicalmed8090430>
- Sariti, S.R. and Elammari, N.E. (2021) 'Anti-leishmanial drug Pentostam induced histological changes to liver and kidney in male BALB/c wild mice', Albayan Scientific Journal, 9, pp. 592–604.
<https://doi.org/10.37375/bsj.vi9.2313>
- Tsurim, I., Wasserberg, G., Warburg, A., Abbasi, I., Ben Natan, G. and Abramsky, Z. (2023) 'Large scale systemic control short-circuits pathogen transmission by interrupting the sand rat (*Psammomys obesus*)-to-sand fly (*Phlebotomus papatasi*) *Leishmania major* transmission cycle', Medical and Veterinary Entomology, 37(1), pp. 4–13. <https://doi.org/10.1111/mve.12608>
- van Henten, S., Bialfew, F., Hassen, S., Tilahun, F., van Griensven, J. and Abdela, S.G. (2023) 'Treatment of cutaneous leishmaniasis with sodium stibogluconate and allopurinol in a routine setting in Ethiopia: clinical and patient-reported outcomes and operational challenges', Tropical Medicine and Infectious Disease, 8(8), 414.
<https://doi.org/10.3390/tropicalmed8080414>
- Wijnant, G.-J., Dumetz, F., Dirx, L., Bulté, D., Cuypers, B., Van Bocxlaer, K. and Hendrickx, S. (2022) 'Tackling drug resistance and other causes of treatment failure in leishmaniasis', Frontiers in Tropical Diseases, 3, 837460.
<https://doi.org/10.3389/fitd.2022.837460>
- World Health Organization (WHO) (2021) Ending the neglect to attain the Sustainable Development Goals: a road map for neglected tropical diseases 2021–2030. Geneva: World Health Organization. ISBN 978-92-4-001035-2.
- World Health Organization (WHO) (2022) Ending the neglect to attain the Sustainable Development Goals. One Health: approach for action against neglected tropical diseases 2021–2030. Geneva: World Health Organization. ISBN 978-92-4-004241-4.
- World Health Organization (WHO) (2023) Operational manual on leishmaniasis vector control, surveillance, monitoring and evaluation. Geneva: World Health Organization. ISBN 978-92-4-006034-0.
- World Health Organization (WHO) (2025) 'Global leishmaniasis surveillance updates 2024: consolidating gains and new initiatives', Weekly Epidemiological Record, 100(45), pp. 535–552.