Risk Landscapes for Leishmaniasis Prevention

From Climate Hazard Maps to Risk-Informed One Health Action

The Interconnected Landscape of Leishmaniasis. A One Health perspective illustrates how human settlements, domestic animals, and changing environmental conditions converge to create localised risk zones in a rural area in Portugal.

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Executive Summary

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Sand fly-borne diseases, particularly leishmaniasis, remain a public health concern across Europe and the Mediterranean. Although climate, together with other environmental factors, creates the conditions that allow sand fly vectors to survive, climate change is reshaping those conditions and expanding the potential geographic range of sand flies. However, climate alone does not explain where transmission occurs or why disease burden and severity vary widely across and within countries. Similar climate conditions can produce very different outcomes depending on patterns of human exposure, population vulnerability, and local environmental context. Climate-based hazard maps provide an essential foundation for identifying areas where transmission is biologically possible. Integrating exposure and vulnerability factors helps decision-makers design more focused surveillance and prevention strategies, enabling more efficient resource allocation and prioritisation of where and for whom action will have the greatest impact [1,2].

Leishmaniasis risk results from the interaction of three dimensions: hazard, exposure, and vulnerability [1,3,4]. **Hazard** reflects the presence of vectors and pathogens; **exposure** captures the likelihood of human contact with infected vectors; and **vulnerability** determines the probability of severe disease, shaped by immune status and access to healthcare. Differences in exposure and vulnerability explain why comparable hazards can lead to very different public health impacts.

Drawing on the CLIMOS Risk Factor Analysis (Danyang et al., 2026; available online at **RFA** [21]), which examined 700 socio-economic, climatic, and environmental variables, this brief translates evidence from multiple interacting variables into a policy-oriented framework for interpreting leishmaniasis risk. The findings suggest that no single driver dominates across settings: socioeconomic and vulnerability-related factors are often central, climate contributes variably, and risk profiles differ between and within countries. Rather than ranking factors or producing predictions, this framework supports structured interpretation of risk to guide targeted prevention.

This brief provides a practical way to interpret risk profiles within a One Health framework and translate them into concrete guidance to support effective, equitable, and context-specific decisions across surveillance, prevention, and health-system response.

Key messages for decision-makers

- Climate maps show where sand flies can live, but not necessarily where people get sick.
- Leishmaniasis risk depends on hazard, exposure, and vulnerability; similar hazards can produce very different public health impacts.
- One-size-fits-all measures can lead to misallocation of resources. Prevention strategies work best when actions are tailored to local risk.

1. Background and Context

Leishmaniasis is a neglected vector-borne disease with a complex transmission ecology involving sand fly vectors, multiple animal reservoirs, and heterogeneous human risk profiles [5,6]. Across Europe and the Mediterranean, both cutaneous and visceral forms persist, with a disease burden unevenly distributed and disproportionately affecting vulnerable populations, particularly individuals with compromised immune systems, as well as certain groups with increased exposure or limited access to prevention and care, including rural communities and mobile or displaced populations in specific contexts [5,7,8].

In recent decades, climate change, land-use change, urban growth, and other environmental pressures have expanded or intensified environmental suitability for sand fly vectors in several regions. As a result, climate-based suitability models and hazard maps have increasingly been used to support preparedness and prevention planning [1,2,9]. While these tools are valuable for identifying where transmission is biologically possible, they provide limited guidance for prevention on the ground [9–11].

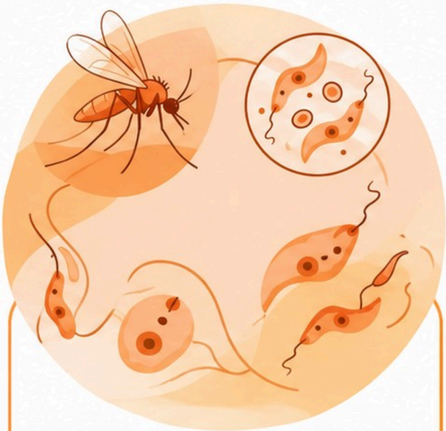
Experience across countries shows that areas with similar climatic conditions often display very different transmission patterns and disease burdens [12,13]. In practice, leishmaniasis risk is shaped not only by environmental factors but also by human-related activities and access to timely diagnosis and treatment [8,12,14]. These factors determine who is exposed, who is vulnerable, and where transmission persists or re-emerges.

European and Mediterranean frameworks increasingly prioritise climate adaptation and preparedness within a One Health framework [15–17]. This policy brief responds to that need by proposing a structured, risk-informed approach to guide decision-making across diverse settings.

Everyday rural systems shape transmission: animal husbandry and land-use patterns influence sand fly ecology and human exposure risk

2. From Hazard to Risk: An Operational Framework for Prevention Planning

Public health decision-making on leishmaniasis requires understanding not only where transmission is biologically possible, but also how environmental conditions interact with human behaviour, animal reservoirs, population vulnerability, and health-system capacity.
For prevention purposes, leishmaniasis risk can be understood through three interacting dimensions: hazard, exposure, and vulnerability [13,18]:



Hazard
The biological threat

The presence and abundance of sand fly vectors and the circulation of Leishmania parasites in vectors and animal reservoirs, including domestic and wildlife species, where relevant [12,19].

Exposure
Human contact likelihood

The likelihood of contact with infected sand flies is shaped by housing quality, occupational and outdoor activities, mobility, peridomestic environments, and changing urban and peri-urban landscapes that facilitate interactions with infected animals.

Vulnerability
Systemic susceptibility

The probability that infection results in morbidity or severe outcomes is influenced by immune status, age, comorbidities, nutrition, and access to timely diagnosis and treatment [3,4].

These dimensions reinforce one another: overall risk increases when any of them intensifies, even if the others remain stable.

Risk = Hazard × Exposure × Vulnerability

This relationship is intended as an interpretative framework rather than a quantitative model.

As a result, areas with similar environmental suitability (hazard) can experience very different disease patterns depending on how exposure and vulnerability align locally [4]. Conversely, high exposure or vulnerability may remain invisible in hazard-based assessments until disease is already established.

The hazard - exposure - vulnerability framework reflects patterns identified in the CLIMOS Risk Factor Analysis (Danyang et al., 2026; available online at RFA [21]), which examined 700 environmental, social, and health-related variables across settings, and is translated here into a policy-oriented risk interpretation tool (Figure 1). This showed that leishmaniasis risk follows a shared underlying structure but is expressed through different dominant drivers across settings. Rather than ranking factors or producing predictions, the framework provides an operational lens for interpreting complex evidence, identifying which dimensions drive risk in a given context, and guiding more targeted prevention planning.

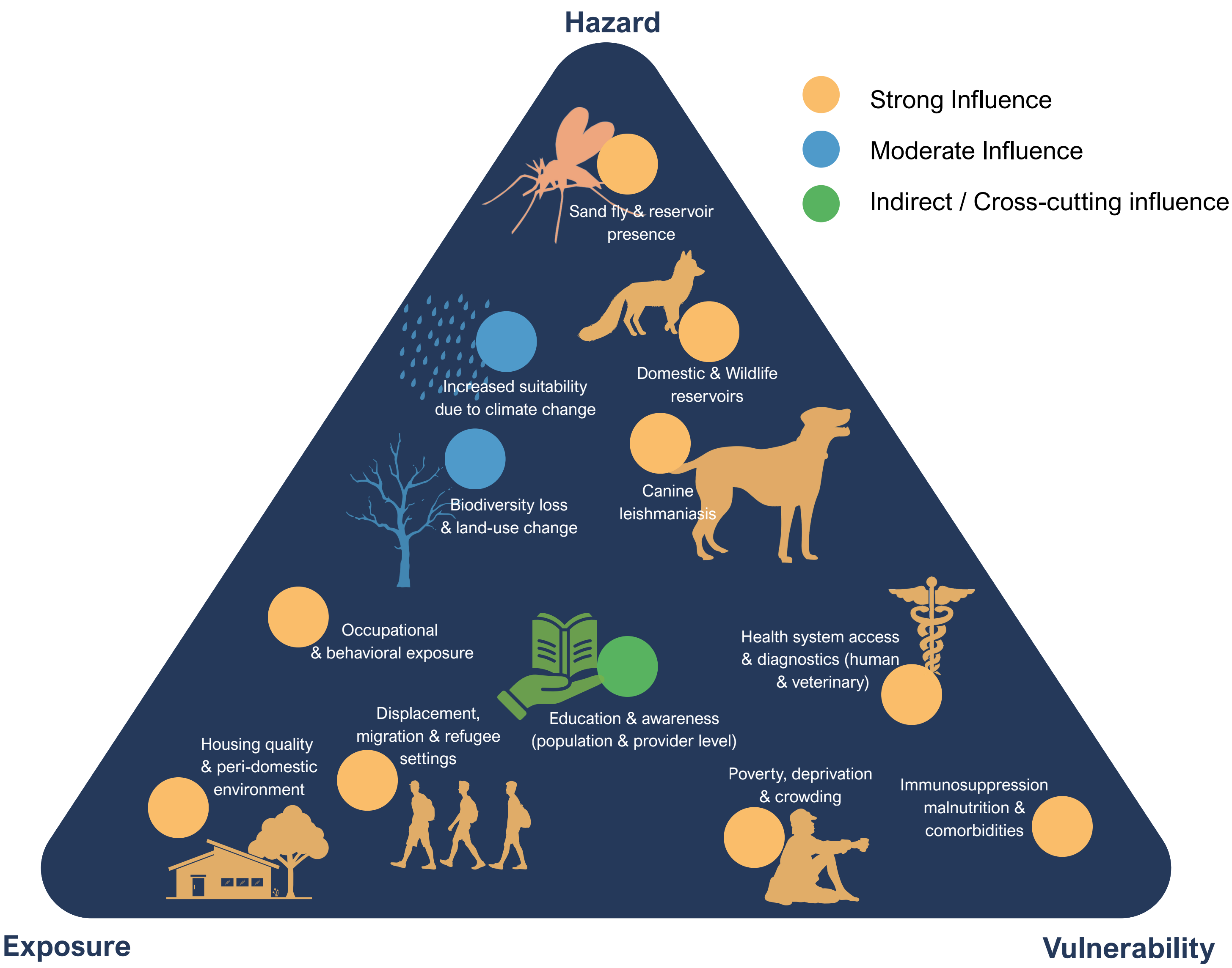


Figure 1. Risk triangle showing how determinants "pull" leishmaniasis risk toward hazard, exposure, or vulnerability. Each label is positioned deliberately within the triangle: variables placed closer to a vertex are interpreted as having a stronger conceptual contribution to that dimension (a qualitative "pull" or weighting), while variables nearer the centre reflect shared influence across dimensions. This spatial logic is intended to support integrated risk profiling by highlighting dominant drivers and interactions in a given setting, rather than ranking factors numerically or producing predictions.

3. Evidence from CLIMOS: Context-Specific Risk Profiles

Evidence from the CLIMOS project, supported by national surveillance data and published studies, shows that leishmaniasis risk is heterogeneous and context-specific across Europe and the Mediterranean. The CLIMOS Risk Factor Analysis indicates that no single driver consistently explains risk across settings. Instead, leishmaniasis risk varies across settings because hazard, exposure, and vulnerability interact differently from place to place.

In many regions, socioeconomic conditions shape both exposure and vulnerability, while climate contributes mainly to hazard and varies across contexts [4,18].

As a result, similar environmental conditions can produce very different transmission patterns and disease burdens. Multiple risk profiles may coexist within the same country, reflecting ecological diversity, population heterogeneity, and differences in access to prevention and care.

Illustrative context-specific risk profiles identified include:

Greece: Risk is strongly shaped by occupational exposure in agriculture and forestry, single-dwelling housing, warm and dry climatic conditions, and the presence of canine leishmaniasis infection.

Italy: Vulnerability-related factors, including underlying health conditions and demographic patterns, contribute substantially to risk, alongside climatic suitability and Leishmania circulation in canine populations.

France: Risk reflects a combination of climate suitability, occupational exposure, housing, and social vulnerability in specific population groups, with biodiversity loss showing a weak negative association.

Spain: Risk is influenced primarily by vulnerability and demographic structure, including immunosuppression and case-demographic patterns (higher representation of working-age men), while climate and environmental suitability remain important for differentiating lower-risk Atlantic northern areas from higher-suitability regions.

Portugal: Exposure-related drivers dominate, including dog and cat populations, human demography (females more than males), and occupation patterns that increase human-vector contact.

Israel: Multiple overlapping anthropo-zoonotic (between humans and animals) transmission cycles involving different reservoir hosts (e.g., dogs, hyraxes, rodents) generate distinct urban and peri-urban areas, linked to construction and synanthropic wildlife, and rural risk profiles, rather than a single national pattern.

Türkiye: Long transmission seasons, widespread climatic suitability, population mobility, and large displaced and refugee populations living in high-exposure conditions combine to produce complex and heterogeneous risk profiles.

These profiles reflect pan-European analysis and highlight dominant drivers at a broad scale; finer sub-national gradients may be more apparent in country-level assessments. Their purpose is to demonstrate that leishmaniasis risk profiles are not driven by a single factor; they reflect how hazard, exposure, and vulnerability together shape transmission and disease burden in practice.

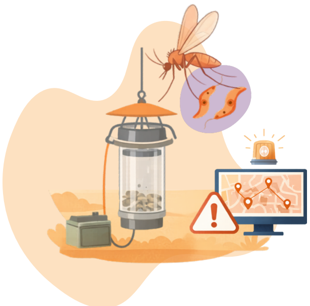
4. From Risk Profiles to Effective Prevention

The variability of leishmaniasis risk profiles has direct implications for policy and planning. Approaches that rely primarily on climate suitability maps or reported case numbers provide limited guidance on who is exposed, who is vulnerable, and where transmission is likely to persist or re-emerge. As a result, interventions are often implemented too late or applied uniformly in settings where risk drivers differ substantially.

Risk-informed prevention requires aligning interventions with the dominant drivers shaping risk in each context. Using a hazard–exposure–vulnerability lens allows decision-makers to move beyond one-size-fits-all measures and to select prevention actions that address the factors most likely to sustain transmission or lead to severe outcomes.

Where exposure dominates (e.g., occupational or peri-domestic transmission), prevention should focus on reducing human–vector contact through targeted awareness, personal protective measures, improved housing or shelter conditions, and management of peri-domestic environments.

Where vulnerability dominates (e.g., high levels of immunosuppression or barriers to healthcare), early detection, clinical awareness, and integration of leishmaniasis into existing care pathways are critical to reduce severe disease and mortality.



Where hazard is high or changing (e.g., expanding vector presence or pathogen circulation), strengthened entomological and veterinary surveillance and early warning mechanisms support timely response and containment.

Effective prevention also depends on coordination across sectors and levels of governance. Human, animal, and environmental health authorities must work together to interpret risk profiles, share information, and align actions. Regional cooperation across Europe and the Mediterranean further strengthens preparedness by enabling consistent interpretation of risk, coordinated responses in cross-border areas, and more efficient use of resources.

Translating risk profiles into targeted action can support earlier intervention, better prioritisation, and more equitable protection of vulnerable populations. Smarter prevention is not about adding complexity but about using existing evidence more effectively to act where it matters most.

The implication is clear: prevention strategies must be aligned with dominant local risk profiles rather than applied uniformly across settings.

5. Recommendations: The IMPACT-R Framework

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Translating integrated risk information into effective prevention requires coordinated action at both national and regional levels. The IMPACT-R framework summarises key recommendations and operationalises risk-based prevention within a One Health approach. Its components are mutually reinforcing and can be implemented in parallel, adapted to national capacities and local risk profiles.

Risk-informed action (R) is a cross-cutting governance function that ensures implementation by clarifying responsibilities, coordinating decisions across sectors, and reviewing outcomes so that integrated risk information consistently leads to action (Figure 2).

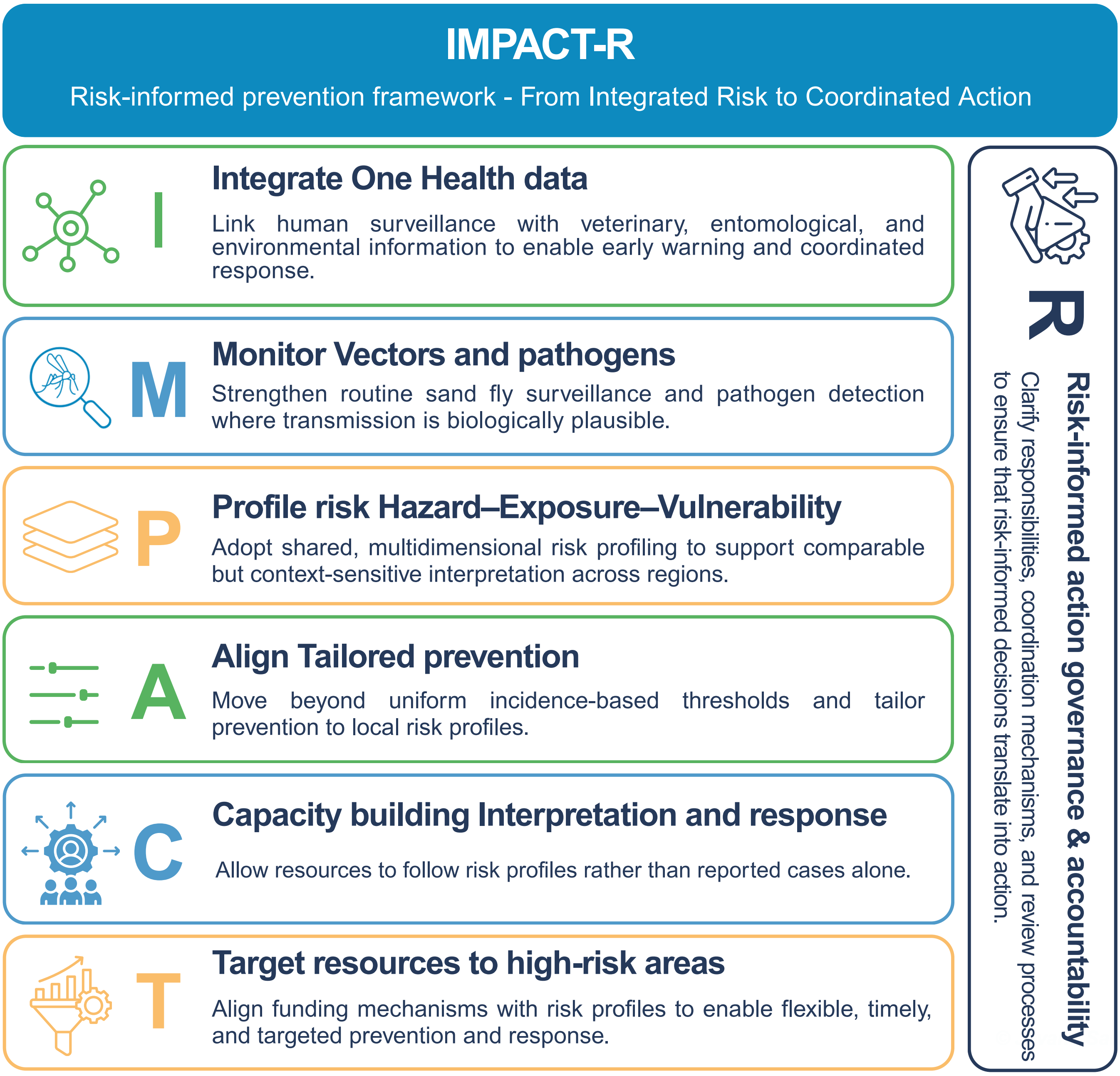

Figure 2. The IMPACT-R framework for risk-informed prevention. The framework translates integrated risk information into coordinated action through six mutually reinforcing components, supported by a cross-cutting governance function (Risk-informed action) to ensure that evidence consistently leads to implementation.

6. Conclusion

Preventing leishmaniasis in Europe and the Mediterranean requires more than mapping or modelling where sand flies may occur. It requires understanding who is at risk, why they are at risk, and how prevention systems can respond effectively.

By recognising that for sand fly-borne infections, risk follows a shared hazard–exposure–vulnerability structure while being expressed through context-specific driver configurations, policy makers and practitioners can move from broad prediction to targeted prevention. The objective is to ensure that complex analysis and modelling translate into effective prevention, enabling more efficient use of resources, stronger protection of vulnerable populations, and more resilient responses grounded in real-world risk landscapes.

The same risk-based perspective is also relevant beyond leishmaniasis. Sand flies transmit phleboviruses such as Toscana virus and Sandfly Fever Sicilian Virus, which can cause febrile illness and, in some cases, neurological diseases. Applying this integrated framework can therefore strengthen surveillance, diagnostic readiness, and clinical awareness for sand fly-borne infections more broadly, particularly in areas where sand fly exposure is already recognised.

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