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## Spatiotemporal dynamics of vector-borne disease risk across human land-use gradients: examining the role of agriculture, indigenous territories, and protected areas in Costa Rica

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# Spatiotemporal dynamics of vector-borne disease risk across human land-use gradients: examining the role of agriculture, indigenous territories, and protected areas in Costa Rica

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## Abstract

**Background** Costa Rica has undergone significant changes to its forest ecosystems due, in part, to the proliferation of palm oil and other industrial agriculture operations. However, the country also boasts conservation programmes that are among the most robust in the neotropics. Consequently, gradients of anthropogenic to intact ecosystems are found throughout the country. Forest ecosystems may decrease vector-borne disease (VBD) risk by maintaining insect populations in a state of relative equilibrium; however, evidence suggests that intact forests foster biodiversity and may also amplify VBD risk in some circumstances. As a result, focal points of human-vector contact are likely idiosyncratic. This may be particularly true in indigenous territories, which have been shown to play a vital role in maintaining the ecological integrity of conservation areas. Here, we investigate the relationships between anthropogenic landscapes, indigenous territories, protected areas, and risk of VBD.

**Methods** We quantified spatial dynamics of risk across three distinct categories of VBD in Costa Rica: emerging flaviviruses (Zika virus disease and dengue); neglected tropical diseases (cutaneous leishmaniasis and Chagas disease); and a disease nearing eradication (malaria). We collected district-level incidence data from between 2006 and 2017 and used spatial statistics to identify hotspots of elevated risk. We then quantified the associations between anthropogenic landscapes, intact forest ecosystems, and indigenous territories with both the presence and persistence of elevated transmission risk over time using multivariate hurdle models.

**Findings** We detected clear patterns of non-random disease risk across each of the three categories of VBD. Compared with protected areas, districts with higher proportions of human-altered landscapes, particularly agricultural intensification, were at higher risk for VBD across all categories. Districts with the highest proportion of crop cover, compared with the lowest proportion, were significantly associated with the presence of hotspots for Zika virus disease (OR 15·19 [95% CI 6·19–37·26]), dengue (13·00 [7·24–23·35]), leishmaniasis (4·46 [1·18–16·84]), Chagas disease (3·09 [1·47–6·49]), and malaria (8·40 [3·56–19·83]).

**Interpretation** A set of spatial epidemiology tools within a planetary health framework allowed for a refined understanding of the risk of VBD of global public health significance in a biodiversity hotspot. Our findings may be used to better guide targeted public health disease surveillance, control, and prevention programmes. Additional research to understand the role that socioeconomic factors play in the varying VBD risk would contribute additional context to these findings, as these factors are often also spatially associated.

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## Declaration of interests

We declare no competing interests.

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