

Associations between reported leishmaniasis incidence, conflict intensity, and environmental factors, 2005 – 2020

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Introduction

- Leishmaniasis is a vector-borne protozoan infection spread by the *Phlebotomus* sandfly
 - Cutaneous (CL) and mucocutaneous (ML) are two presentations of disease
- CL: 600,000 to 1 million cases annually, causes lesions on skin and high stigma
- ML: partially or completely destroys nose, mouth, and throat mucous membranes
- Cases have risen globally over last several decades
- Increase in cases attributed to environmental changes and conflict
 - Environment: temperature, deforestation and other similar changes, precipitation, humidity, vegetation, displacement due to environmental events
 - Conflict: infrastructure destruction, displacement, poor living conditions, poverty, interrupted vector control measures
- Aim: assess the associations between conflict, environmental factors, and joint CL & ML incidence in countries reporting cases to the WHO between 2005 and 2020**

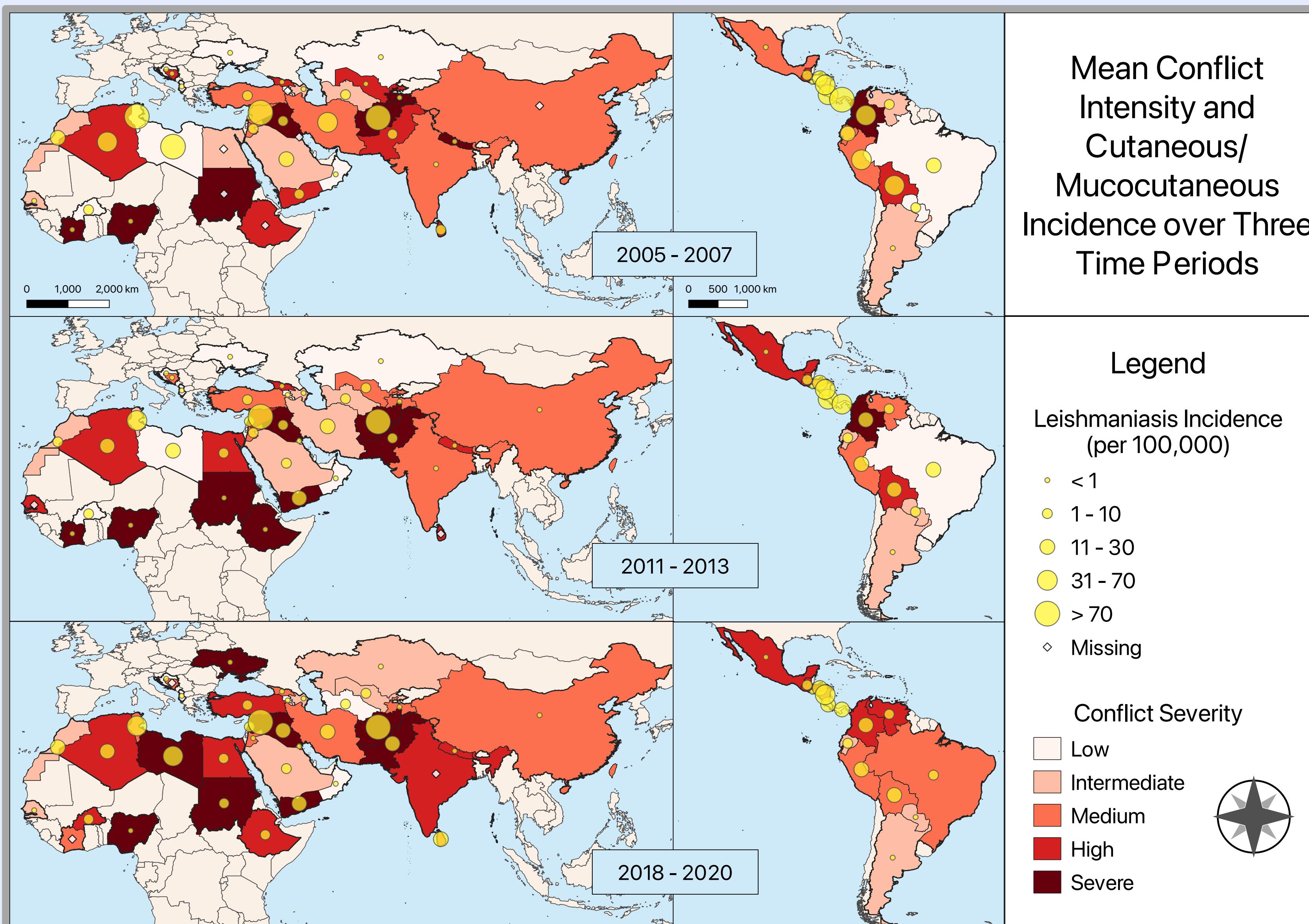


Figure 1: Mean conflict intensity and cutaneous and mucocutaneous leishmaniasis incidence per 100,000 in 2005 - 2007, 2011 - 2013, and 2018 - 2020 for countries in the analysis. We created the maps using QGIS v 2.33.1.

Methods: Data Sources

- Temporal: Annual (16 years), 2005 to 2020
- Geographical: 53 countries with a) at least 8 years of reported cases and b) conflict intensity scores
- Leishmaniasis case and population data: WHO Global Health Observatory (cases), World Bank (population)
- Conflict intensity: Bertelsmann Transformation Index
 - Uses country experts to measure social, ethnic, and religious conflict severity on scale of 1 (low) to 10 (severe)
 - Divided into intensity levels by quintiles
 - Low: 1 – 3 score
 - Intermediate: 3.5 – 4
 - Medium: 4.5 – 5
 - High: 5.5 – 7
 - Severe: 7.5 – 10
- GDP: World Bank (in USD)
- Displacement: International Displacement Monitoring Center
- Environmental Data: World Bank's Climate Change Knowledge Portal (precipitation and temperature), NASA's Global Land Data Assimilation System Land Surface Model (humidity)
- Random intercept used to account for repeat observations within countries over time

Methods: Model Building

- Generalized additive model (GAM) with a negative binomial probability distribution and country-level random intercept
- Conflict intensity lagged by one year based on model fit statistics and scientific hypotheses
- Robustness testing: sequentially added groups of related variables to base model (Model A), which accounted for year, conflict intensity, GDP, and had the country-level random intercept

Final Model Equation

$$\text{cases} = \beta_0 + \beta_1(\text{year}) + \beta_2(\text{GDP}) + \beta_3(\text{intermediate_CI}) + \beta_4(\text{medium_CI}) + \beta_5(\text{high_CI}) + \beta_6(\text{severe_CI}) + \beta_7(\text{precipitation}) + f_1(\text{temperature_mean}) + \beta_8(\text{temperature_range}) + f_2(\text{humidity_mean}) + \beta_9(\text{humidity_range}) + \beta_{10}(\text{displacement})$$

Where β_0 is the random country-level intercept, $\beta_3 - \beta_6$ are lagged at t - 1, and f_1 and f_2 are smooth functions estimated by the model using restricted maximum likelihood. CI: conflict intensity

Results: Forest Plot

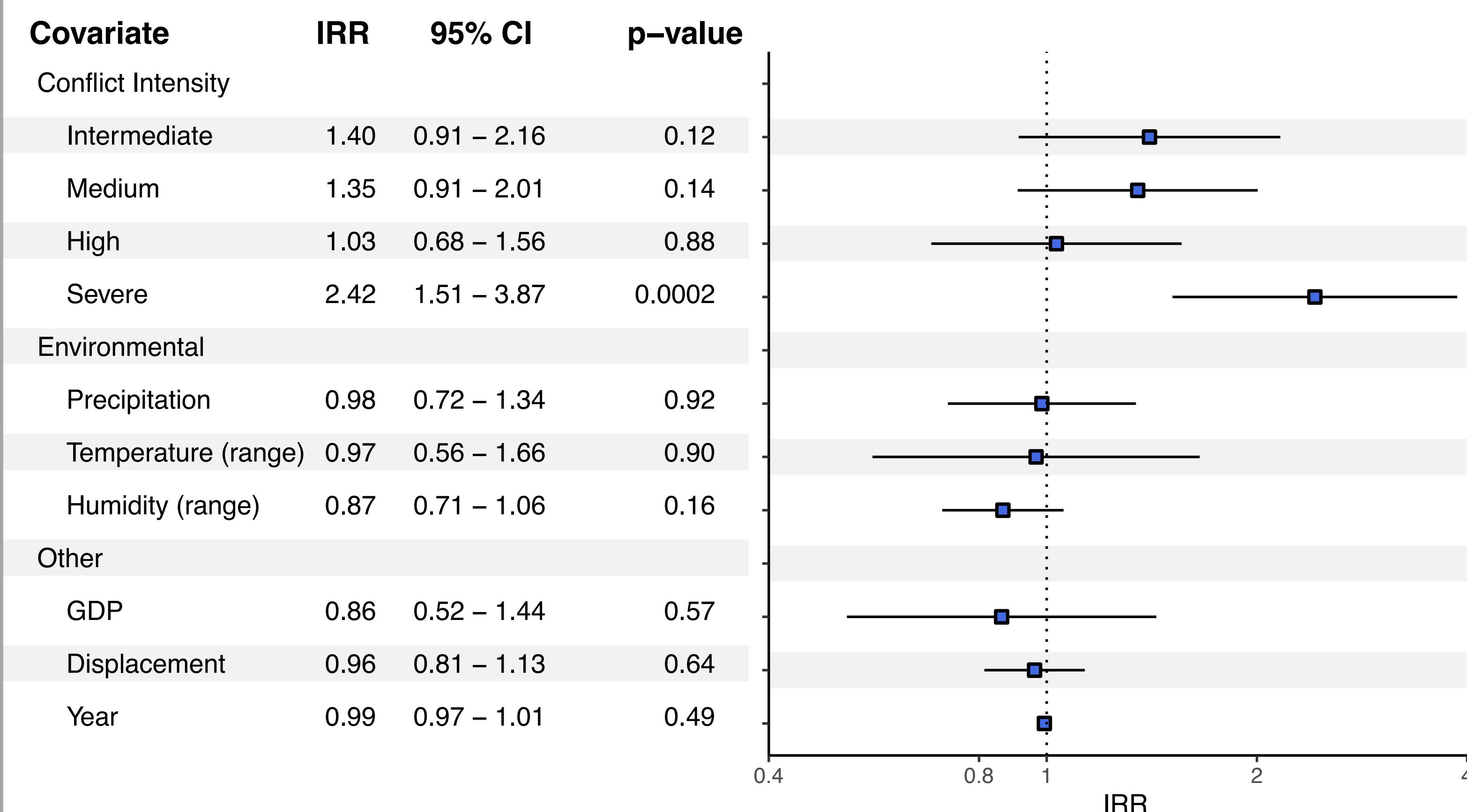


Figure 2: Plot of the IRRs and associated confidence intervals. Results are significant when the confidence interval does not go through the null of one. GDP = Gross Domestic Product. IRR= Incidence Rate Ratio

Results

- 3,337,084 cases of CL and ML over study period (Figure 1)
 - Syria had highest number of cases and mean incidence
- Mean conflict intensity: 5.2, increased over study period
- Countries with severe conflict intensity had over double the risk (2.42) of CL/ML incidence compared to countries with low levels of conflict (Figure 2)**
- Lower mean temperature protective against CL/ML incidence (Figure 3)
 - Temperatures between ~18.47°C - 25.10°C are associated with higher risk
- Displacement acted as a potential mediator between conflict and disease incidence**
 - Improved model fit when added as a variable (AIC of 2,083.67 versus 2,835.07) and grew severe conflict intensity IRR (2.42 versus 1.87)

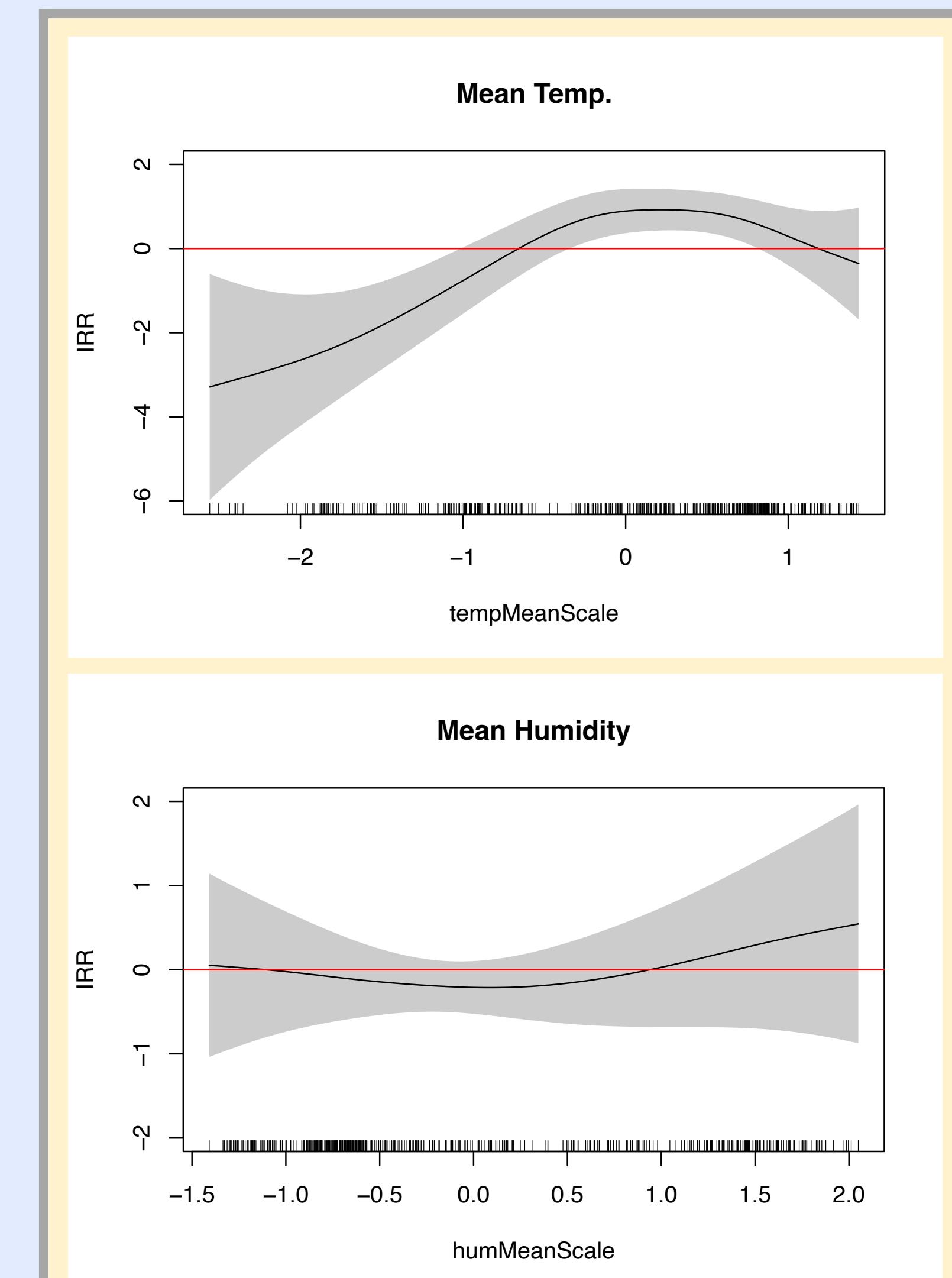


Figure 3: Mean temperature (top) and mean humidity (bottom) spline outputs. The red lines can be used to measure significance, whereby the output is significant when the entire grey area (indicating the 95% confidence intervals) is either above or below the blue line. The y-axes indicate the IRR associated with the value of each variable on the x-axis.

Discussion

- Severe conflict, which is when conflict turns largely violent, is associated with increased risk of leishmaniasis incidence
- Violence, and its ensuing destruction, is likely driving this association**
 - May be due to the creation of appropriate breeding sites, wide-scale displacement, and damage and destruction of relevant vector control infrastructure, and poverty
- Temperature association may be sandfly vector's optimal temperature