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Influences of rainfall and temperature trends on the transmission and control of visceral leishmaniasis (VL)

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Visceral leishmaniasis (VL), also known as kala-azar, is a significant global health concern caused by more than 90 species of sandflies. Climate factors such as temperature and rainfall substantially influence the life cycle of sandflies and the transmission dynamics of VL. Most existing VL models assume constant responses of sandfly and parasite life-history traits to these climate variables. However, incorporating climate variability into models could improve predictive accuracy and support more effective disease prevention and control strategies.

In this article, we propose an SEIR-type model for VL transmission that accounts for seasonal variations of rainfall and temperature by introducing periodic sandfly recruitment, biting, and mortality rates. The non-autonomous differential equations model is calibrated using observed meteorological and epidemiological data from Ethiopia, a VL-endemic region. The time-averaged basic reproduction ratio for a non-autonomous system is calculated. The simulation result identifies key temperature-sensitive parameters that significantly affect disease transmission. The recruitment and natural death rates of sandflies, along with the human recovery rate and both natural and disease-induced death rates of humans, are among the most sensitive model parameters within the temperature range of $16 - 32^\circ$ C. The calibrated model is forced by rainfall and temperature variables super imposed with observed trends after 522 weeks to assess the impact on VL transmission and control.

The basic reproduction ratio exhibits periodic behavior, peaking at moderate weekly temperatures with minimal rainfall, and reaching its lowest values

during temperature and rainfall peaks. Simulations reveal that a reduction in temperature at a rate of 0.417 per decade creates conditions more favorable for sandflies, potentially increasing VL transmission, while a wetting trend in rainfall leads to a significant reduction in the total number of infected humans. The results indicate that, by the end of 800 weeks, an increase in rainfall at the rate of 0.062 per decade leads to a 68.69% reduction in the total number of infected individuals relative to the baseline. Implementing a maximum of 50% effective vector control effort can reduce the VL cases by 65.39% in the current trend of climate change.

The findings reveal the significance of temperature and rainfall variability in shaping VL transmission dynamics and climate-sensitive intervention strategies in mitigating the spread of the disease. The findings also underscore the need for the assessment of future VL transmission and control options under the ongoing Intergovernmental Panel on Climate Change (IPCC) scenarios to develop adaptation and mitigation measures.

Keywords: visceral leishmaniasis, climate change, temperature and rainfall dependent parameters, non-autonomous model, vector control

References

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