iScience

CellPress
OPEN ACCESS

Article

Climate change maladaptation for health: Agricultural practice against shifting seasonal rainfall affects snakebite risk for farmers in the tropics

Eyal Goldstein,[1,2,*] Joseph J. Erinjery,[1,3] Gerardo Martin,[4] Anuradhani Kasturiratne,[5] Dileepa Senajith Ediriweera,[6] Ruchira Somaweera,[7] Hithanadura Janaka de Silva,[8] Peter Diggle,[9,10] David G. Lalloo,[11] Kris A. Murray,[12] and Takuya Iwamura[1,13]

SUMMARY

Snakebite affects more than 1.8 million people annually. Factors explaining snakebite variability include farmers' behaviors, snake ecology and climate. One unstudied issue is how farmers' adaptation to novel climates affect their health. Here we examined potential impacts of adaptation on snakebite using individual-based simulations, focusing on strategies meant to counteract major crop yield decline because of changing rainfall in Sri Lanka. For rubber cropping, adaptation led to a 33% increase in snakebite incidence per farmer work hour because of work during risky months, but a 17% decrease in total annual snakebites because of decreased labor in plantations overall. Rice farming adaptation decreased snakebites by 16%, because of shifting labor towards safer months, whereas tea adaptation led to a general increase. These results indicate that adaptation could have both a positive and negative effect, potentially intensified by ENSO. Our research highlights the need for assessing adaptation strategies for potential health maladaptations.

INTRODUCTION

Climate change has caused large-scale social and ecological impacts, affecting multiple aspects of life on earth.[1] In response, societies are increasingly adapting or planning adaptation strategies to reduce the risks of a changing climate. Where such responses designed to protect infrastructure, livelihoods or well-being inadvertently increase other risks, such as the direct or indirect health impacts of climate change, climate maladaptation may result. Clearly, it is necessary to evaluate the potential risks of climate change adaptation strategies alongside the intended benefits, particularly where these may harm human health.

Snakebite is climate-sensitive neglected tropical disease (NTD) particularly affecting rural farmers and communities living in tropical areas,[2] with up to 1.8 million bites and up to 94,000 deaths annually.[2,3] Rural farmers and communities in the tropics are also on the frontline of climate change impacts, and are increasingly adopting strategies to reduce the impacts of a changing climate on their livelihoods, health and well-being. These strategies may target protecting crop yields in the face of rising temperatures and changing patterns of precipitation, which could include switching to more climate-resilient crop types, changing crop rotation schedules, or changing daily activity patterns. Given snakebite is driven by complex social, ecological, and economic interactions,[4] such climate change adaptation strategies have clear potential to directly influence farmer exposure to snakes and subsequently snakebite risk. Understanding the potential impact of farmer adaptation strategies on snakebite risk is therefore an important but currently overlooked component of meeting the targets of the WHO snakebite roadmap to 2030.[5,6]

Existing studies highlight both social and ecological factors influencing snakebite incidence, including occupational and behavioral traits of affected populations alongside climate and other factors related to snake ecology. Different models have, for example, estimated the contribution of climatic factors,[4] venomous snake distributions,[7] and extreme weather events to snakebite risk.[8–10] In addition, models have predicted changes in the risk of snakebite because of climate change, as a result of changes in

[1]School of Zoology, Department of Life Sciences, Tel Aviv University, Tel Aviv, Israel

[2]Ecosystem Modeling, University of Göttingen, Göttingen, Germany

[3]Department of Zoology, Kannur University, Kannur, India

[4]Escuela Nacional de Estudios Superiores unidad Mérida, Universidad Nacional Autónoma de México, Yucatán, México

[5]Department of Public Health, Faculty of Medicine, University of Kelaniya, Kelaniya, Sri Lanka

[6]Health Data Science Unit, Faculty of Medicine, University of Kelaniya, Ragama, Sri Lanka

[7]School of Biological Sciences, University of Western Australia, Perth, WA, Australia

[8]Deparment of Medicine, Faculty of Medicine, University of Kelaniya, Ragama, Sri Lanka

[9]CHICAS, Lancaster University Medical School, Lancaster, UK

[10]Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

[11]Liverpool School of Tropical Medicine, Liverpool, United Kingdom

[12]Centre on Climate Change and Planetary Health, MRC Unit the Gambia at London School of Hygiene and Tropical Medicine, Fajara, The Gambia

[13]Department F.-A. Forel for Aquatic and Environmental Science, University of Geneva, Geneva, Switzerland

*Correspondence: eyal.goldstein@forst.uni-goettingen.de

https://doi.org/10.1016/j.isci.2023.105946

weather patterns[11] and changes in venomous snake distributions.[12] These studies are consistent with many others that show that changes in temperature and precipitation patterns and the frequency or magnitude of extreme climate events such as flood or droughts commonly influence the distribution, abundance and behavior of disease causing species, thereby influencing the distribution and burden of many human diseases.[13] For this reason, natural variations in climate, such as those associated with the seasonal movement of the Intertropical Convergence Zone (ITCZ) or the multiyear cycles of El Nino Southern Oscillation (ENSO) are also often also linked to changing patterns of human disease risks. Some of the most significant effects of climate change on human health are linked to its numerous influences on these natural climate cycles; for instance, intensifying ENSO cycles in the tropics has direct implications for climate-sensitive infectious diseases[14] as well as snakebite.[4]

On the socio-economic side, changes in climate and extreme weather events also induce societal changes, such as farmers' adaptation of new behaviors and activity patterns. In some cases, these changes may similarly increase exposure to disease causing species; for example, by increasing the frequency of human-wildlife encounters.[15] In response to climate change, farmers are already trying to mitigate the potential harms of shifting climatic patterns to agriculture with adaptive behaviours.[16] Such adaptation strategies used by farmers include: changes in seasonal patterns of planting because of altered monsoon onset, changes in crop varieties because of increased risk of drought, changing allocation of labor between seasons and hours of the day because of altered and extreme weather patterns, and use of new technologies.[17,18] So far, however, the extent to which climate change adaptation may affect snakebite risk remains unstudied.

Here, we developed a framework to explore how such climate change adaptation strategies could affect snakebite patterns on the island nation of Sri Lanka, a snakebite hotspot with an estimated >30,000 envenomings and 400 deaths by snakebite annually.[19] In Sri Lanka, spatial and temporal patterns of snakebite correlate with climatic conditions.[11] Sri Lankan farmers are particularly vulnerable to snakebites,[36] and temporal peaks of snakebite incidence coincide with peak subsistence agricultural activities, such as rice harvest.[11] Snakebite incidence can also partially be explained by the predicted abundance, distribution and behavioral traits of the key species venomous snakes.[20] Simultaneously, Sri Lankan farmers are also highly vulnerable to climate change as well as changes in ENSO because of climate change,[17,21,22] which are forcing farmers to adapt accordingly. Adaptation strategies used in Sri Lanka include shifting rice planting patterns because of delayed monsoon,[17,23] changes in the allocation of labor in tea plantations as a result of changing rainfall patterns,[21,24] and the introduction of new rubber harvesting methods that are better suited to drought conditions.[25]

When modeling future snakebite burden under climate change, previous research has relied heavily on empirical statistical analysis,[11,26] which has limited value for representing the diversity in individual farmers' behaviors and pinpointing mechanisms that underlie changes in contact between humans and snakes, a fundamental requirement for snakebite to occur in the first place. The present study explores the implications of climate change adaptation strategies on farmers' risk of snakebite using mechanistic agent based models, parameterized with field data, to simulate snake-human contact and predict patterns of snakebite risk.[57] To our knowledge this is the first study to examine the effect of farmers' individual uptake of climate adaptation strategies on snakebite risk under different climatic conditions induced by ENSO. We interpret increases in snakebite incidence in the three major agricultural crops in Sri Lanka (rubber, tea and rice) as examples where changes in agricultural practices to manage climate change risks come at the cost of unexpected human health risks, an example of 'maladaptation'.[27,28] This modeling effort could further help mitigate snakebites and assist in the WHO plan to reduce snakebites mortality by 50% by the year 2030.[29]

METHODS

Study area

Sri Lanka is divided into four different climatic regions characterized by their precipitation levels.[30] Sri Lanka has two monsoonal systems that are highly influenced by El Nino and La Nina phases,[40] and exhibits high rainfall variability[34,40] as well as recurring droughts in both dry and wet regions.[31] Although climate change predictions are highly variable between different regions and altitudes across the island, generally they can be characterized by delay in the timing of monsoonal onset,[23] as well as increased frequency of extreme rain and drought events.[30,31]