Blind spots obscure understanding of how forests affect human health

Health crises have raised awareness of the links between forests and human health. For example, outbreaks of Ebola virus and hypotheses about the origins of SARS-CoV-2 have highlighted the risk of zoonotic spillover events from forest-dwelling animals.[1,2] Likewise, forest fires in Australia (2019–20), the Amazon rainforest (2019), and southeast Asia (2015) have drawn attention to the respiratory health effects on populations exposed to smoke and haze.[3] Other links between forests and health, such as the role of forests in mitigating natural disasters[4] and regulating infectious disease vectors,[5] are well established but less well known outside the scientific community. For example, the loss of coastal mangroves exacerbated morbidity and mortality following the 2004 Indian Ocean earthquake and tsunami,[6] and forest loss amplified the effects of the 2021 flooding across Europe,[7] contributing to injury, increased prevalence of waterborne diseases, and death.

Our understanding of the health benefits and risks forests present to humans is still incomplete. We must urgently detect blind spots in our knowledge to predict and mitigate future health effects caused by forest change. Our systematic global mapping of the empirical evidence linking forests, their management, and human health outcomes reveals a number of geographical, methodological, and thematic gaps (appendix p 1). The 452 articles identified show that global research efforts are poorly aligned with at-risk populations revealing significant gaps in research effort on important forest–health pathways.

The studies' geographical distribution suggests that formal risk mapping could support the targeting of subsequent work in areas at greatest risk. A few countries dominate global research efforts; half of all studies occurred in one of six countries—the USA, Brazil, India, Malaysia, China, and Canada—and over 80% of the studies were in high-income and upper-middle-income countries. Less than 10% of studies occurred in sub-Saharan Africa, and only 4% occurred in forested low-income countries (appendix p 8).

The studies only mentioned a few mechanisms linking forests to health (figure). The most studied pathways were those linking vector-borne disease transmission to forest extent or change (49%), and respiratory illnesses linked to forest fires (12%). Malaria and Lyme disease were well represented, accounting for 16% and 10% of all studies, and 30% and 20% of vector-borne disease studies, respectively. However, insufficient research examines the links between forest-related exposure and neglected tropical diseases such as Chagas disease, leishmaniasis, and dengue.

The study of forests and health linkages requires a new research approach, as the methods used in the reviewed literature are insufficient to describe the full impact of forests on health. They often measure intermediate risk factors without considering the level of exposure of populations to risk factors. 47% of
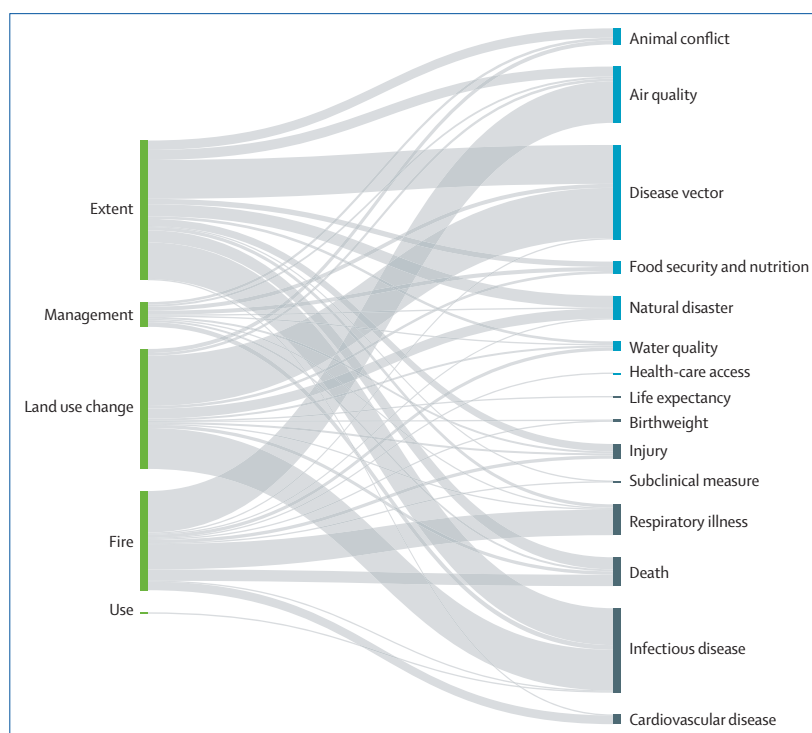
See **Online** for appendix

Figure: Proportion of 452 studies targeting forest–health linkages
Nodes represent exposure (green), intermediate outcomes (blue), and health outcomes (grey). Exposures include forest extent (including measures of forest area, forest cover, and the presence or absence of forest); management (such as commercial or conservation activities); land use change (conversion of forest to other land uses, including deforestation and forest fragmentation); and use (such as time spent in forest). Outcomes are divided into health outcomes (including measures of mortality and morbidity, and subclinical and pre-clinical measures of health and physiological status) and intermediate outcomes (including risk factors, correlates, and predictors of health outcomes). The thickness of the lines corresponds to the number of links found in the 452 studies. The thicker the line, the more frequently those connections are represented in the literature. Studies that measure multiple exposures or outcomes fall into multiple categories.

studies measured a health outcome directly, and only 32% measured the intermediate risk factor and health outcome needed to examine a causal pathway. Where causal mechanisms are well established—for example in studies linking forest fires to respiratory illness, or forest loss to disease vector prevalence—studies often do not include estimates of prevalence or exposure to health outcomes in human populations. Without knowing the size of populations exposed and quantifying risk factors for health outcomes, it is impossible to calculate the risk, morbidity, and mortality estimates needed to initiate action. Likewise, estimates of the economic and social effects of forest–health interactions are needed to bring forest–health linkages to the attention of policy makers. Providing the evidence base needed will require breaking out of disciplinary silos, and clear indications of this progress would be a general increase in the number of publications or multidisciplinary journals beyond the 8% currently published.

Our systematic map suggests new forest and health research directions must be pursued. First, there must be increased research for neglected pathways and under-represented human populations, especially in sub-Saharan Africa and low-income countries with extensive forests and rapid forest-related land use change. Second, studies should, where possible, explicitly link intermediate outcomes to direct measures of human health, providing quantitative estimates of exposures and health burdens. Finally, the complexity of forest and health pathways should be accounted for by scaling up transdisciplinary and multidisciplinary approaches that involve cross-disciplinary collaboration among ecologists, economists, epidemiologists, anthropologists, geographers, and others. As we understand more than ever that the natural environment and public health are intertwined, not exploring these linkages using multidisciplinary perspectives would ignore the forests for the trees.

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