Messaging Should Reflect the Nuanced Relationship between Land Change and Zoonotic Disease Risk

ANDRÉ D. MADER, NEIL A. WATERS, ERIN C. KAWAZU, MICHELLE MARVIER, NOÉMIE MONNIN, AND DANIEL J. SALKELD

A hallmark of the media publicity surrounding COVID-19 has been the message that land change causes zoonotic diseases to spill over from wild animals to humans. The secondary peer-reviewed literature sends a similar message. However, as indicated in the primary peer-reviewed literature, the complexity of interacting variables involved in zoonotic disease spillover makes it unlikely for such a claim to be universally applicable. The secondary peer-reviewed literature and the mainstream media also differ markedly from the primary peer-reviewed literature in their lack of nuance in messaging about the relationship between land change and spillover risk. We advocate accurate, nuanced messaging for the sake of the local communities at greatest risk from zoonotic disease, for the sake of scientific credibility, and so that proportionate attention may be given to other possible drivers of spillover risk.

Keywords: COVID-19, degradation, habitat fragmentation, land use, science communication

Although the source of SARS-CoV-2 remains uncertain, the most widely publicized theory of its origin has been zoonotic spillover from a wild animal or animals at a Wuhan wet market (World Health Organization 2021a). This theory has, unsurprisingly, directed attention toward the potential risks to human health posed by direct contact with wildlife (Halbwax 2020). Between 40% and 50% of emerging infectious diseases in human beings are believed to have come from wild animals, feral animals, or captive or farmed wildlife (Jones et al. 2008, Billinis 2013, Haider et al. 2020), including 71.5% of viruses known to infect humans (Olival et al. 2017) and possibly all seven of the human-infecting coronaviruses (Ye et al. 2020).

For less obvious reasons COVID-19 and emerging infectious diseases more generally have been linked with the way humans degrade or destroy nature. A headline in *The New York Times Magazine* posed the question "What do COVID-19, Ebola, Lyme, and AIDS have in common?," answering confidently with "They jumped to humans from animals after we started destroying habitats and ruining ecosystems" (Jaber 2020). CNN reported experts as having said that "rampant deforestation will only uncork more novel viruses" (Weir 2020). A *Guardian* headline announced, "Pandemics result from destruction of nature, say UN and WHO" (Carrington 2020). Considering the world's astounding

diversity of ecosystems, pathogens, vectors, and forms of land change and the almost infinite combinations of these variables, one might expect some variety in the direction of messages on this topic and a little more nuance. However, all 37 news webpages that we sampled (see the supplemental material for our methodology) associated land change (a catch-all phrase that we use here for the many forms of land-use change, land cover change and habitat destruction) with increased spillover risk. We also sampled 95 webpages of organizations, from the World Health Organization (2021b) to the World Bank (Estavão and Kemper 2021). All but one of them conveyed a similar one-sided message.

The validity, accuracy, and implications of messaging that links land change to spillover risk are the focus of the present article. We are not arguing for a different consensus on the relationship between land change and spillover risk. Rather, we are cautioning against the widespread implication that a consensus exists. Our appeal is aimed at scientists, journalists, and anyone else communicating scientific knowledge.

Why question messaging that links land change to disease spillover?

To begin with, the term *land change* includes various discrete states and processes that may have divergent implications for spillover risk. The form of land change that is perhaps most

Land change increases spillover risk   Land change decreases spillover risk
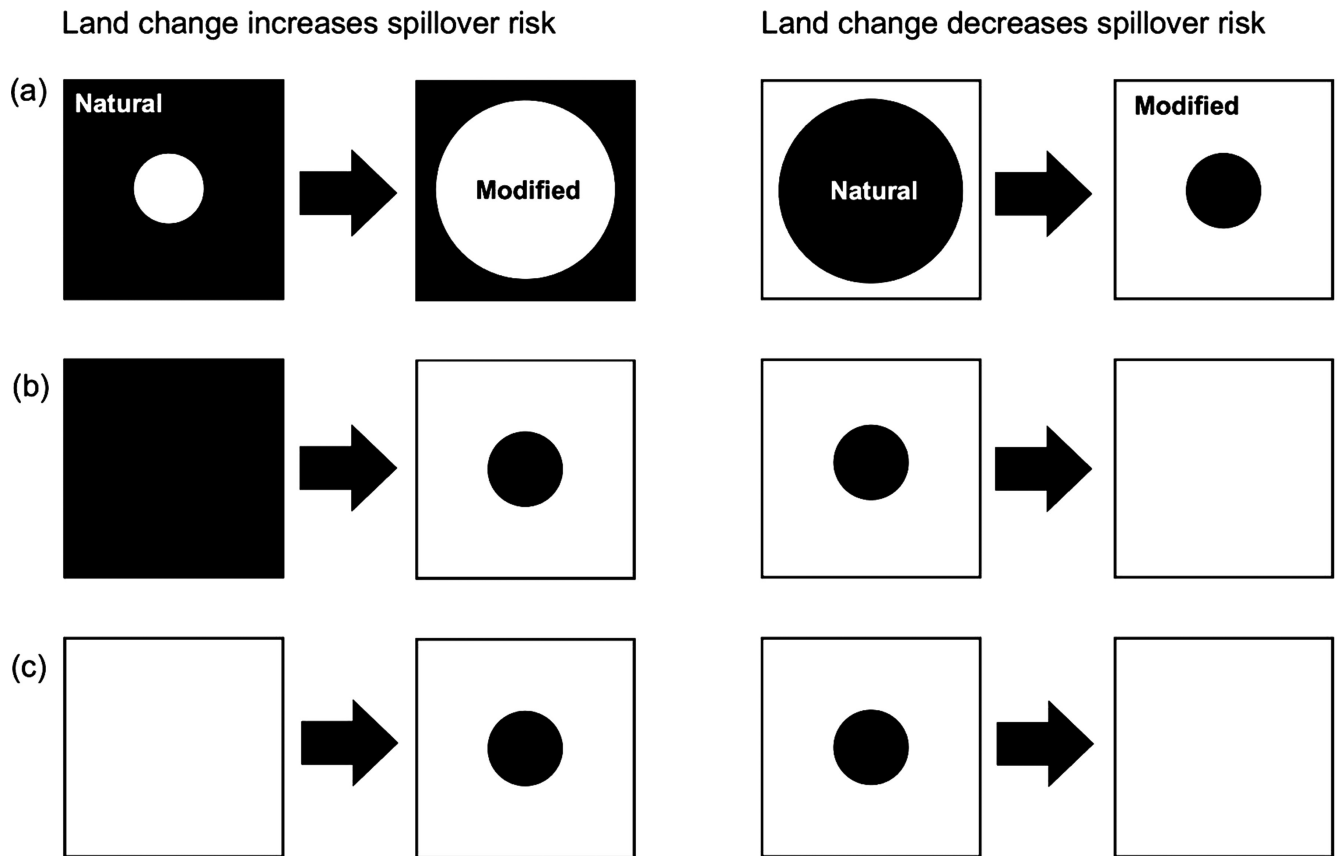

Figure 1. Three simplified hypothetical sets of scenarios in which land change may either increase or decrease zoonotic disease spillover risk. Each assumes that the natural area (black) is the source of spillover, and is devoid of human presence, whereas humans inhabit the modified habitat (white). In panel (a), increasing the size of modified habitat increases edge, and therefore spillover risk, if habitat modification expands outward, but decreases edge and spillover risk if it expands inward. In panel (b), reduction of natural area to fragments introduces an interface, and therefore a risk of spillover. However, if land change continues so that the fragment disappears altogether, there is once again no interface and therefore no spillover risk. In panel (c), restoration or creation of a fragment of natural area amid modified habitat could increase spillover risk, according to theory on habitat fragmentation. As in panel (b), removal of the fragment theoretically removes that risk.

convincingly and commonly implicated in spillover risk is habitat fragmentation. Fragmentation typically increases the interface between natural and modified habitats (Beasley et al. 2013, Allen and Wesner 2016, Kleinschroth and Healey 2017, Borremans et al. 2019, Brock et al. 2019), which potentially increases human contact with wildlife and their pathogens (Hosseini et al. 2017, Faust et al. 2018). But this does not account for the fact that an *inward* expansion of modified habitat could result in *decreased* interface between natural and modified habitat (figure 1a). Along similar lines, if a fragment of natural habitat is the sole source of a zoonotic disease, then the complete destruction of that fragment could eliminate the risk of spillover altogether (figure 1b). Furthermore, "fragments" of nature can also be *created*—for example, by establishing a natural park within a city, which is regarded as being beneficial to human health (Elmqvist et al. 2015). The fragmentation rhetoric, in contrast, implies that creating such fragments would increase spillover risk,

and their removal, by extension, would decrease that risk (figure 1c).

When it comes to the *process*, as opposed to the pattern, of land change, spillover risk is challenging to model because of the complexities of wildlife host and pathogen dynamics (Alexander et al. 2012). But some differences in risk are intuitive. Burning vegetation, for example, involves minimal human–wildlife contact and decreases the abundance of some pathogens (Albery et al. 2021), although smoke may help to spread others (Kobziar and Thompson 2020). Logging, on the other hand, more predictably exposes people to wildlife and their pathogens and for longer (Faust et al. 2018).

Whatever the process or the pattern of land change, it is thought that some adaptable and mobile wildlife, such as rodents, may respond by resettling in adjacent human habitat, taking their pathogens with them (Altizer et al. 2011, Hernández-Camacho et al. 2012, Ferreira-Junior et al.

2018, Mendoza et al. 2020, Santini 2021). It is, however, not certain whether their relocation is a response to land change or simply a preference for accessible human habitat. Indeed, the literature on the relationship between land change and spillover risk seems sometimes to conflate proximity to nature per se, with proximity to the "newly exposed" nature that land change brings about.

These scenarios are partly just thought experiments, but they illustrate how difficult it can be to assess the risk of zoonotic spillover without knowing the amount, spatial pattern, and type of land change, not to mention zoonotic disease prevalence in wildlife, and incidences from which spillover could take place. Even when pathogen prevalence increases in wildlife populations, we still lack data and insights into the concomitant change in risk of exposure and transmission to human populations in the modified environment. Unsurprisingly, therefore, some authors acknowledge that the relationship between land change and spillover risk remains poorly understood (Sehgal 2010, Cumming et al. 2015, Suzán et al. 2015, Mastel et al. 2018, Stark et al. 2019, Davey and Selvey 2020, White and Razgour 2020, Plowright et al. 2021, Reaser et al. 2021). The complexity of pathogen responses to land change cannot be reduced to simple one-size-fits-all proclamations.

Reviewing the rhetoric

Most primary research on the relationship between land change and spillover risk reports increased spillover risk with land change (Plowright et al. 2008, Beasley et al. 2013, Vanwormer et al. 2013, Scinachi et al. 2017, Santos and Almeida 2018). However, other authors report mixed results (Young et al. 2017, Afelt et al. 2018, Maaz et al. 2018, Young et al. 2021) and even decreased risk (Kowalewski et al. 2011, Shapiro et al. 2020, Riquelme et al. 2021). In some cases, the drainage of marshland (Jacups et al. 2011) and the removal of vegetation (Ducheyne et al. 2009), for example, have protected local communities from zoonotic disease.

We sampled 145 peer-reviewed papers with abstracts that made statements about the relationship between land change and spillover risk. Only 43 papers reported on the authors' own findings on this relationship (primary research, including empirical studies and models), 23 of which (53%) associated land change with increased spillover risk. This proportion is roughly consistent with the findings of a systematic literature review by Gottdenker and colleagues (2014), in which 57% of studies documented increased pathogen transmission, whereas 43% observed decreased pathogen transmission, variable and complex pathogen responses, or no detectable changes. Other factors thought to influence rates of pathogen spillover (e.g., the loss of biodiversity, which is intertwined with land change) also turn out to be complex and heterogeneous in both the strength and the direction of the relationship (Wood et al. 2014, Rohr et al. 2020). In all of these cases, nonsignificant results (i.e., no relationship between land change and spillover risk) are likely to be underreported, as is expressed in the file drawer problem (Sterling 1959, Csada et al. 1996, Wood 2020, West and Bergstrom 2021).

In contrast to the variability evidenced in primary papers, we found that, of the 102 secondary papers (peer-reviewed review articles and commentaries) we sampled, 78% associated land change with increased spillover risk. This apparent overstating of the evidence was even more pronounced among the webpages we sampled, only one of which did not associate land change with increased spillover risk.

Messaging also differed in terms of nuance. Although 79% of primary papers acknowledged uncertainty in the way they communicated their findings about the relationship between land change and spillover risk, this figure was 53% for secondary papers and 31% for webpages. Although 51% of primary papers indicated that the relationship was not necessarily causal, this figure was 10% for secondary papers and 4% for webpages. Although 74% of primary papers specified the pathogens responsible, this figure was 30% for secondary papers and 17% for webpages. Although 60% of primary papers specified the geographical location to which the relationship between land change and spillover risk applied down to the ecosystem or local scale, this figure was 3% for both secondary papers and webpages.

Peer-reviewed research can be expected to be more specific and nuanced than mainstream messaging, as was indicated in the primary papers we sampled. However, by some of the measures mentioned above, the specificity and nuance in *secondary* peer-reviewed papers was more akin to mainstream sources than to the primary research on which it is ostensibly based. Furthermore accuracy matters regardless of whether a message is communicated to a scientific or a general audience. Giving the impression that a phenomenon is universally applicable, when the empirical research suggests otherwise, is inaccurate and potentially misleading in any context.

Implications of simplistic messaging

Media attention to COVID-19 has been used as an opportunity to advocate the value of nature as a defense against future pandemics. But there are considerable risks in drawing oversimplified and generic conclusions from complex and nuanced phenomena. Gregg and colleagues (2021) pointed out how well-intentioned rhetoric could inadvertently send a message precisely opposite to the message intended: implying that nature is a threat to humanity because of the thousands of viruses lurking unseen within it. We propose three additional arguments for accuracy and nuance.

First, policy or management decisions that are based on simplistic messaging risk neglecting local context. Policymakers and other decision-makers must understand that context if they are to make appropriate decisions for their communities. Solutions required at the local level will vary considerably with location and ecosystem, across species of pathogen, vector, and host, and across different forms of land change. Restoration or conservation of the

local environment is not guaranteed to decrease spillover risk. If vectors or reservoir hosts happen to be dependent on certain habitats (see, e.g., Bradley and Altizer 2007), the conservation of those habitats near human settlement might make spillover more likely. Honest appraisals and mitigation of spillover risk are required in order to prioritize public health, although they may narrow down the options for simultaneously achieving conservation objectives.

Second, when messaging turns out to be false or inaccurate, it can erode credibility. Every conservation message has the potential to contribute positively or negatively to the reputation of conservation and even of science more broadly, depending largely on the care with which it attempts to approximate the truth. In a survey of attitudes on public trust in science, Kreps and Kriner (2020, p. 1) noted that "careful science communication is critical to maintaining public support for science-based policies as the scientific consensus shifts over time." They argued that this risk is magnified by the public attention garnered by COVID-19. If the disease turns out to have no links with land change, then strongly worded headlines about protecting nature for the sake of public health are less likely to be taken seriously next time around. Examples of such consequences include public mistrust in scientific information on climate change and vaccines (Rowland et al. 2022) and on nutrition (Nagler 2013, Garza et al. 2019).

Third, cases in which messaging implies that land change is the *sole* reason for spillover can detract from other important spillover risks. Especially on the webpages we sampled, it was not rare for messaging to give the impression that spillover risk is entirely dependent on land change. This could divert attention from other factors that may increase zoonotic disease spillover risk, such as the wildlife trade (Karesh et al. 2005), wildlife farming (Magouras et al. 2020 and the references therein), global travel (Baker et al. 2022), climate change (Carlson et al. 2022), socioeconomics (Power et al. 2022), and transmission to researchers working on zoonotic diseases (National Research Council 2012).

Recommendations

Science communication, whether in peer-reviewed journals or the mainstream media, is meant to make scientific knowledge understandable. When it comes to topics as complex as the relationship between land change and zoonotic disease spillover, we contend that science communicators are more likely to succeed at that task when messaging is accurate and carefully nuanced. To that end we offer the following recommendations, using the relationship between land change and spillover risk as an example:

Messaging should specify context and explanatory variables such as the relevant ecosystem, scale, pathogen, vector, host, form of land change, confounders, and effect measure modifiers. The strength of effect linking land change to zoonotic spillover risk within that context should also be communicated when possible. A message is true only within the specific context for which evidence exists and, if that context is not stated, then the message is not being communicated accurately. When generalization is unavoidable it should, at least, be acknowledged that a generalized conclusion is being communicated.

Defined and consistent terminology—for example, to specify type of land change—can facilitate clearer communication both within science and to the broader public (Herrando-Pérez et al. 2014, Fraser et al. 2015, Peacor et al. 2020). Undefined and inconsistent terminology in some of our sampled papers and webpages made them difficult to compare with one another—an observation shared by others (Gottdenker et al. 2014).

Messaging that describes the mechanisms that underlie phenomena is more likely to be accurate, to facilitate understanding, and to allow practitioners to identify leverage points for intervention. For example, a brief explanation of the mechanism underlying the effect of land change on spillover risk in a particular context may tell the reader more about the conditions under which that effect can be expected in future. Although science communicators cannot be expected to provide all of the relevant detail, we noted a lack of any explanation—or even a mention—of the mechanisms linking land change to spillover risk in some of the less nuanced messaging that we sampled.

Finally, the simple acknowledgement of uncertainty and exceptions can be enough to capture nuance, even in pithy social media posts.

Having said this, recipients of science communication would do well to remember that science communicators are human beings too. The motivations behind messaging vary: Interest groups might be tempted to cherry-pick science that supports their cause, media outlets are rewarded by numbers of copies or clicks, and, with the advent of indices such as the Altmetric Attention Score, scientists may be motivated to extend the reach of their work.

Conclusions

The last time the world experienced anything like COVID-19 was when the Great Influenza pandemic struck in 1918. At that time, it was still common for messaging to rely on carrier pigeons and dispatch riders. It predated the first radio news program by 2 years, and the first trans-Atlantic telephone call was still almost a decade away. A century later, with the click of a button, a message can instantly reach millions. The present article was written out of concern for the potential consequences of simplistic messaging at that speed and scale—including messaging about one of the most significant events of our lifetime. It was written in the hopes of encouraging more nuanced discourse, both within and beyond the peer-reviewed literature. If the goal of science communication is to improve understanding, it must strike a balance: sufficient simplicity to be grasped by as broad an audience as possible but sufficient nuance to capture the complexity of an issue

and contribute meaningfully to the discussion around it, especially when it goes viral.

Supplemental material
Supplemental data are available at *BIOSCI* online.

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André D. Mader (mader@iges.or.jp) is a programme director at the Institute for Global Environmental Strategies, in Hayama, Kanagawa, Japan. Neil A. Waters (nawaters3@gmail.com) is a postgraduate student in the Division of Environmental Studies at the University of Tokyo, in Kashiwa, in Chiba Prefecture, Japan. Erin C. Kawazu (kawazu@iges.or.jp) is a program coordinator at the Institute for Global Environmental Strategies, in Hayama, Kanagawa, Japan. Michelle Marvier (mmarvier@scu.edu) is a professor in the Department of Environmental Studies and Sciences at Santa Clara University, in Santa Clara, California, in the United States. Noémie Monnin (noemiebmonnin@gmail.com) is a postgraduate student in environment and sustainable development at University College London, in London, England, in the United Kingdom. Daniel J. Salkeld (dan.salkeld@colostate.edu) is a research scientist in the Department of Biology at Colorado State University, in Fort Collins, Colorado, in the United States.