



## D4.2 EXPERT ELICITATION

Expert elicitation on the impact of land use change and landscape restoration on zoonotic disease transmission risks

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# 1. Executive summary

This report uses expert elicitation to improve our understanding of trends and the impacts of land use changes and restoration on the risk of transmission of zoonotic diseases. A total of 59 experts took part in the study, 27 of whom had experience on research or applied projects related to landscape restoration (“restoration experts”). These 59 experts worked on a wide range of case studies (mostly terrestrial) spread globally: 17 in Europe, 15 in Africa, 14 in North America, 13 in South America, 10 in Asia, and three in Oceania.

Although the effects of land use change on the transmission of zoonotic diseases were generally considered negative, with an increased risk of disease transmission associated with land use change, only 15% of the 27 restoration experts surveyed believed that restoration generally has a similar impact. However, the perceived effects **were more uncertain** in restoration study systems. For example, although 59% of restoration experts reported that **negative effects on zoonotic disease transmission were likely or already happening** (11% of whom reported it as a known or common occurrence in their study systems), around two thirds perceived positive restoration effects on zoonotic disease transmission, leading to its reduction, as likely or already happening. Ticks, mosquitoes and rodents were perceived as the most common vectors linked to potential negative effects. While most diseases were mentioned as being both facilitated and reduced in restoration systems, Lyme disease was considerably more frequently mentioned as being facilitated than reduced by restoration.

In addition, although 15% of restoration experts believed that the potential negative impact of restoration on the transmission of zoonotic diseases in their study systems would be major or severe, this was generally considered to be a moderate or low risk. Conversely, the negative consequences of land use change were considered to be much more impactful. However, around one third of restoration experts were either unsure or noted that these impacts vary depending on factors such as the specific disease, scale and process. **The duration and reversibility of these potential negative consequences were particularly uncertain among experts.**

Around half of the expert participants working in restoration initiatives perceived a **general level of unpreparedness to cope with the transmission of zoonotic diseases** in their study systems. This prevalence was even higher among experts working on land use change initiatives. Weak governance and coordination, insufficient funding and surveillance capacity, low awareness and knowledge, and the poor integration of zoonotic risk into land use and restoration planning, particularly at community and implementation levels, were identified as key barriers to preparedness.

Key policy recommendations identified by the experts converged on integrating zoonotic disease risk into land-use and restoration planning through a mandatory One Health approach, supported by long-term surveillance, strong public health and veterinary systems, community engagement, and governance structures that prioritise prevention, equity, and cross-sector coordination.

## 2. Context

Ecological restoration has emerged as a central component of global environmental agendas, as demonstrated by the Paris Agreement, the Bonn Challenge and the New York Declaration on Forests, driving political and financial commitments aimed at halting the decline of forest ecosystems and promoting the well-being of the communities that depend on them (Oldekop et al., 2025). In this context, the United Nations Decade on Ecosystem Restoration represents a unique opportunity to restore vast areas of degraded land and advance the achievement of multiple Sustainable Development Goals (Aronson et al., 2020). While restoration is generally considered to be an ecological process, it is increasingly recognised as being socio-ecological in nature, requiring the integration of environmental, social and economic objectives and involving multiple actors, interests and values (Sacande et al., 2021).

Although the ecological outcomes of restoration are increasingly documented, its socioeconomic and health impacts on local populations remain comparatively understudied (Choksi et al., 2023). By enhancing ecosystem integrity and services, restoration may reduce risks associated with zoonotic disease transmission (Wood et al., 2014). However, certain stages of restoration, particularly the initial phases, can temporarily increase interactions among people, domestic animals, and wildlife, potentially elevating exposure to pathogens (Jagadesh et al., 2023). Restoration can also affect how people relate to “nature,” which makes it less straightforward to implement (Balaguer et al., 2014).

However, the literature review conducted in RESTOREID’s WP1 revealed that research examining the impact of restoration efforts on disease spillover is limited (Fell et al. in press). The review also revealed a clear geographic and economic bias in the global research landscape, with almost half of the studies concentrated in just four countries: the USA, Brazil, Kenya and Malaysia. Research was also found to be biased towards certain disease hosts and vectors, such as mosquitoes, rodents and ticks. However, the scarcity of data from empirical research should not prevent the development and implementation of strategies (Halpern et al., 2007). Furthermore, delays in reporting and publishing results, as well as a tendency to avoid negative findings, could result in the loss of valuable information when relying solely on literature (Catalano et al., 2019; Christie et al., 2021). Alternative ways of collecting data, such as expert elicitation, are therefore necessary. Expert knowledge refers to substantive information on a topic that is not widely known but that may be obtained from training, research, skills or personal experience (Martin et al., 2012).

This study thus aimed to gain a better understanding of the trends and impacts of land use change and restoration on zoonotic disease transmission risks. In particular, we:

1. Assessed prevalence, causes, impacts/consequences and risk severity of land use change and restoration on zoonotic disease transmission;
2. Defined preparedness to cope with zoonotic disease transmission risks (including within restoration projects);
3. Identified measurable criteria and indicators to identify zoonotic disease transmission risks within restoration initiatives and determine priorities for wildlife pathogens surveillance;

4. Synthesized research needs and expert-recommended solutions and policy levers for mitigating potential short-term risks while preserving long-term restoration goals.

Ultimately, these findings should be used to produce actionable recommendations to support the development and adoption of science-based policy solutions for restoration initiatives using a One Health approach.

### 3. Methods

The study was based on a structured questionnaire, which the experts were asked to complete online. The questionnaire was designed in order to complement findings obtained from the literature review conducted under WP1 as well as addressing key knowledge gaps identified by the project consortium. This tool included questions about the following core topics: prevalence, causes, impacts/consequences and risk severity of land use change or restoration on zoonotic disease transmission; preparedness to cope with zoonotic disease transmission risks and priorities for wildlife pathogens surveillance; and research needs and recommendations. Additionally, experts were asked to provide basic sociodemographic and background information about themselves, as well as some descriptive information about their specific case studies. At the start of the questionnaire, participants were also asked if they currently work, or have previously worked, on research or applied projects related to landscape restoration. If not, all subsequent questions referred to “land use change”, and only those with restoration experience were asked about it specifically. To enhance potential spatial comparisons, participants were also asked to identify a specific study system with which they were familiar and focus their answers on this. The full template questionnaire is provided in the Annex.

Literature authorship and chain-referral are common approaches for identifying participants for expert elicitation studies (e.g. Drescher et al., 2013; Lopes et al., 2022). We identified 212 potential participants who published at least one study discussing the impact of landscape restoration, degradation or land use changes on zoonotic disease transmission risks (detailed in Fell et al., in press) and/or were part of Eklipse’s Expert Working Group on biodiversity and pandemics (Jagadesh et al., 2023), which brings together academic and practitioners working across the biodiversity and pandemic nexus.

Knowledge of linkages between zoonotic disease transmission risks and land use change or landscape restoration is a specialised field of expertise, and therefore we used snowball sampling during survey implementation to identify further individuals. We requested all those directly contacted to recommend up to three peers who may have relevant expert knowledge and experience; this approach, widely used for accessing populations that are hard to reach (Heckathorn, 2011), resulted in the identification of 56 additional participants. In total, 268 potential participant individuals were approached by email; 6 (2%) of these emails were not delivered. Responses were collected between 17 October 2025 and 5 January 2026, and up to two email reminders were sent during this period.

The questionnaire was only administered after the consent of each participant had been obtained. They were informed of the project's purpose, the voluntary nature of their participation, their right to terminate the questionnaire at any time, and that any disclosed data would be completely

anonymous. They were also asked if they would be interested in receiving a summary of the key findings, and if they agreed, their email addresses were obtained and kept confidential. Participants were assured that no one involved in the study would be made aware of the response or opinion of any individual panelist. Data collection was approved by NOVA FCSH’s Ethics Committee (Ref. CE-NOVA\_FCSH\_2025-042).

## 4. Key results

The information below provides a descriptive summary of key findings obtained in this study.

### 4.1. Study participants

A total of 59 participants completed the survey (a response rate of 23%), the majority of whom worked for universities or research institutes and mainly played a role in scientific research at national and international levels (see Table 1). Most participants had considerable experience of issues related to land use change, landscape restoration and/or risks of zoonotic disease transmission, with an average of 17 years' experience working in this field (median; S.D. = 9, ranging from 4 to 46 years). Of the 59 participants, 46% (n = 27) reported that they currently work, or have previously worked, on research or applied projects related to landscape restoration (hereby, “restoration experts”; the others were designated “land use change experts”). Additionally, 97% reported currently working, or having previously worked, on research or applied projects related to zoonotic disease transmission.

A total of 23 nationalities were listed among these 59 participants, with the USA (n = 13), the UK (n = 8) and France (n = 7) being the most frequent. When focusing on the study systems with which they were most familiar, locations were spread globally: 17 in Europe, 15 in Africa, 14 in North America, 13 in South America, 10 in Asia, and three in Oceania. In addition, 90% of participants reported working on terrestrial biomes (including: 23 on tropical-subtropical forests; 15 on temperate-boreal forest and woodland; 5 on shrublands and shrubby woodlands; 5 on savannas and grasslands; and 5 on intensive land-use systems), with four working on palustrine wetlands.

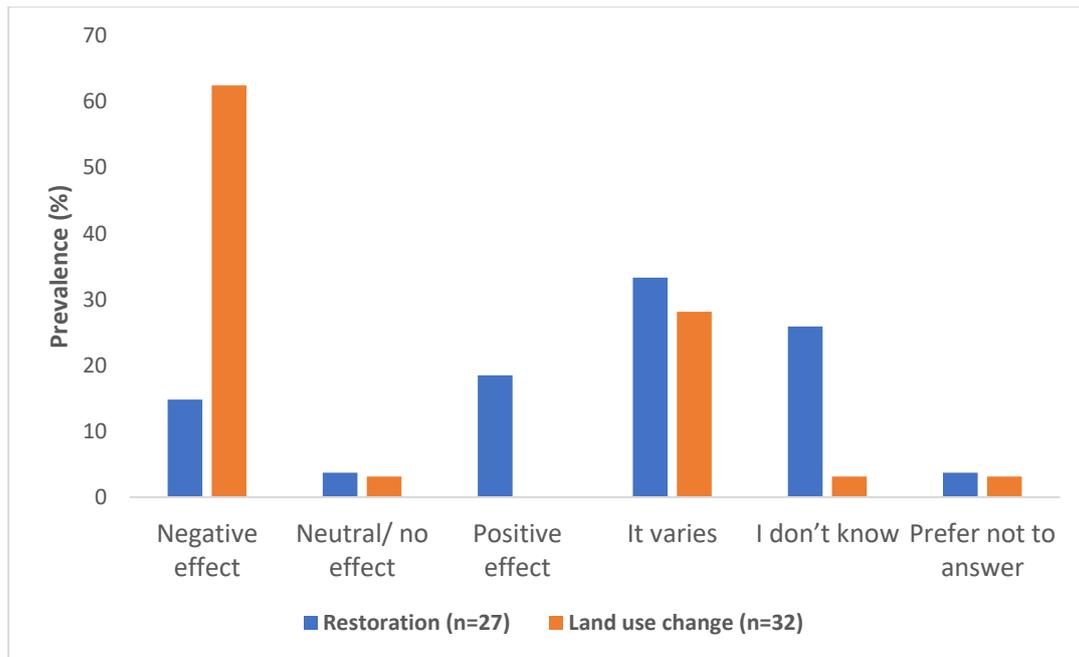
**TABLE 1. CHARACTERISATION OF THE 59 SURVEY PARTICIPANTS.**

Characteristics	Frequency (%)
<b>Type of organization</b> (multiple options allowed)	
University/research institute	49 (83%)
Environmental non-governmental organization	8 (14%)
Governmental agency	8 (14%)
Non-governmental organization related to social issues (including human health)	3 (5%)
Consultancy	2 (3%)
Industry/private sector	2 (3%)
Veterinary health sector	1 (2%)
<b>Main role</b> (multiple options allowed)	
Scientific research	50 (85%)
Program coordination	9 (15%)

Technical ecological work	6 (10%)
Policy making	6 (10%)
Teaching	4 (7%)
Advocacy	3 (5%)
Technical social work	3 (5%)
Consultancy	1 (2%)
Prefer not to answer	1 (2%)
<b>Main scale of work</b>	
International (i.e. involving multiple countries)	28 (47%)
National (i.e. at the scale of a single country)	18 (31%)
Regional (e.g. related to specific region/district/state)	9 (15%)
Local (e.g. related to specific community/ies)	3 (5%)
Prefer not to answer	1 (2%)

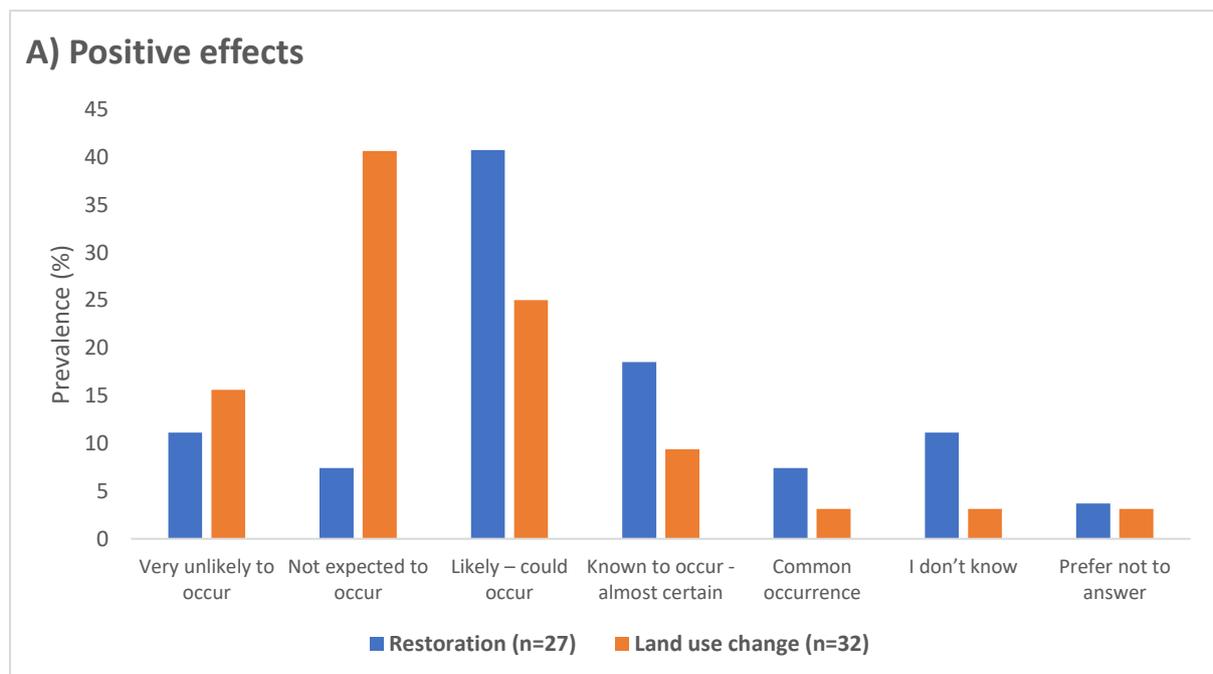
## 4.2. Perceived risks and uncertainties

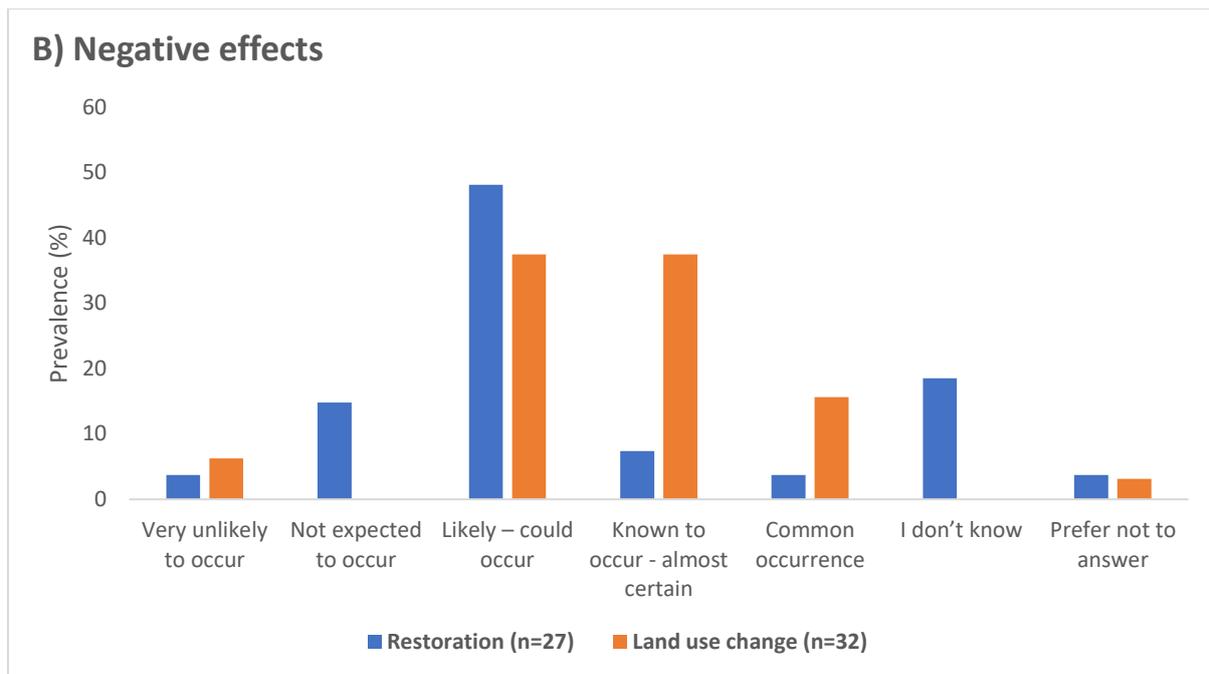
While the effects of land use change on the transmission of zoonotic diseases were perceived by “land use change experts” (LUC experts) to be generally negative, with disease transmission risk increasing with land use change, only 15% of the 27 “restoration experts” surveyed believed that restoration generally has a similar effect (Fig. 1). Furthermore, none of the LUC experts perceived land use change to have a generally positive effect, although 19% of restoration experts thought that disease transmission risk generally decreased with restoration. However, these effects were perceived as more uncertain in restoration study systems, with 26% of restoration experts being unsure. Additionally, around one third of experts noted that these effects can vary considerably (e.g. as mentioned by a land use change expert: *“Generally will depend on the specific pathogen and specific landscape context...and the challenge of ascertaining positive/negative effects”*). A restoration expert also emphasised the need to consider local context: *“Depending on the region, negative in cases where the restoration can increase the contact of domestic, wild animals and humans in condition of low sanitation, etc. (increase risks of spillover)... In other regions, it can be very beneficial for wildlife”*.



**FIGURE 1. PERCEIVED DIRECTION OF EFFECTS OF LAND USE CHANGE OR RESTORATION ON ZOO NOTIC DISEASE TRANSMISSION IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH. NEGATIVE EFFECT: DISEASE TRANSMISSION RISK INCREASES WITH LAND USE CHANGE/RESTORATION. POSITIVE EFFECT: DISEASE TRANSMISSION RISK DECREASES WITH LAND USE CHANGE/RESTORATION.**

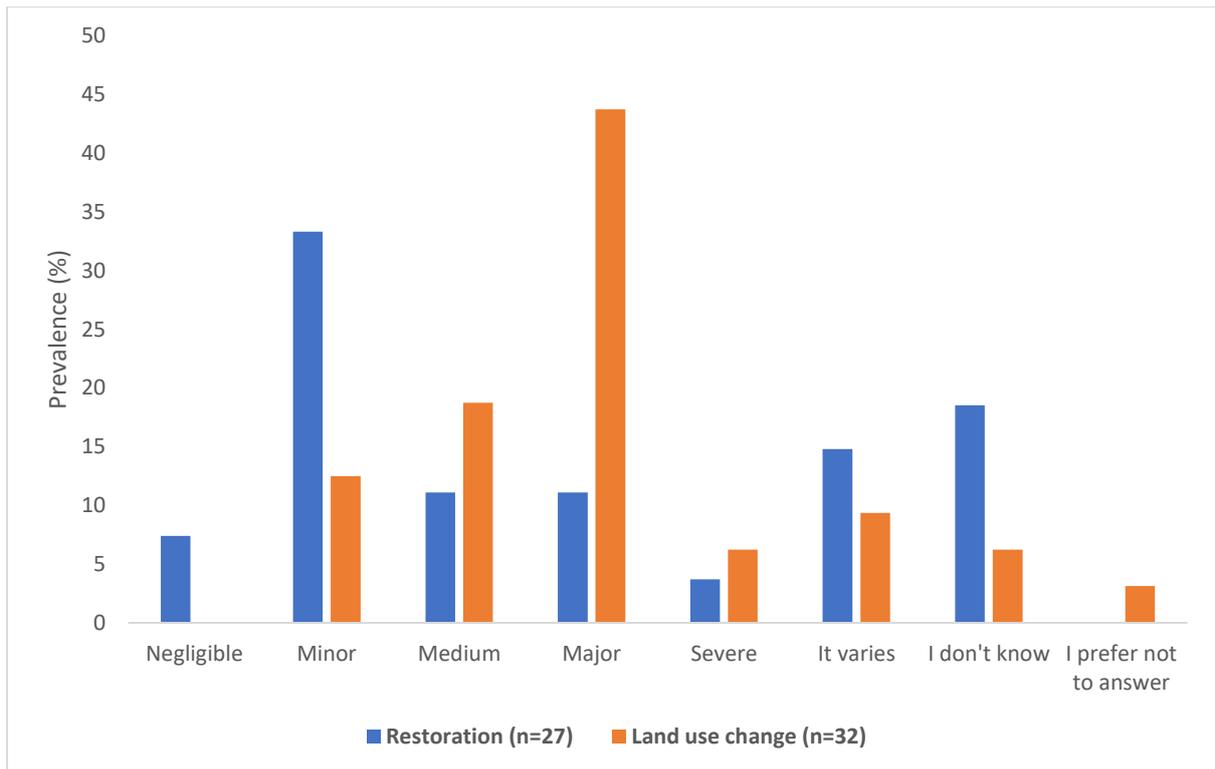
Overall, experts found that the positive effects of land use change were generally less likely than those of restoration initiatives. Negative effects were also perceived to be more likely to result from land use change (Fig. 2). For instance, while 59% of restoration experts believed that an increase in zoonotic disease transmission due to restoration could or already has occurred, this figure was much higher among land use change experts (91%). Nevertheless, only 11% of restoration experts reported this as known to occur or common occurrence.





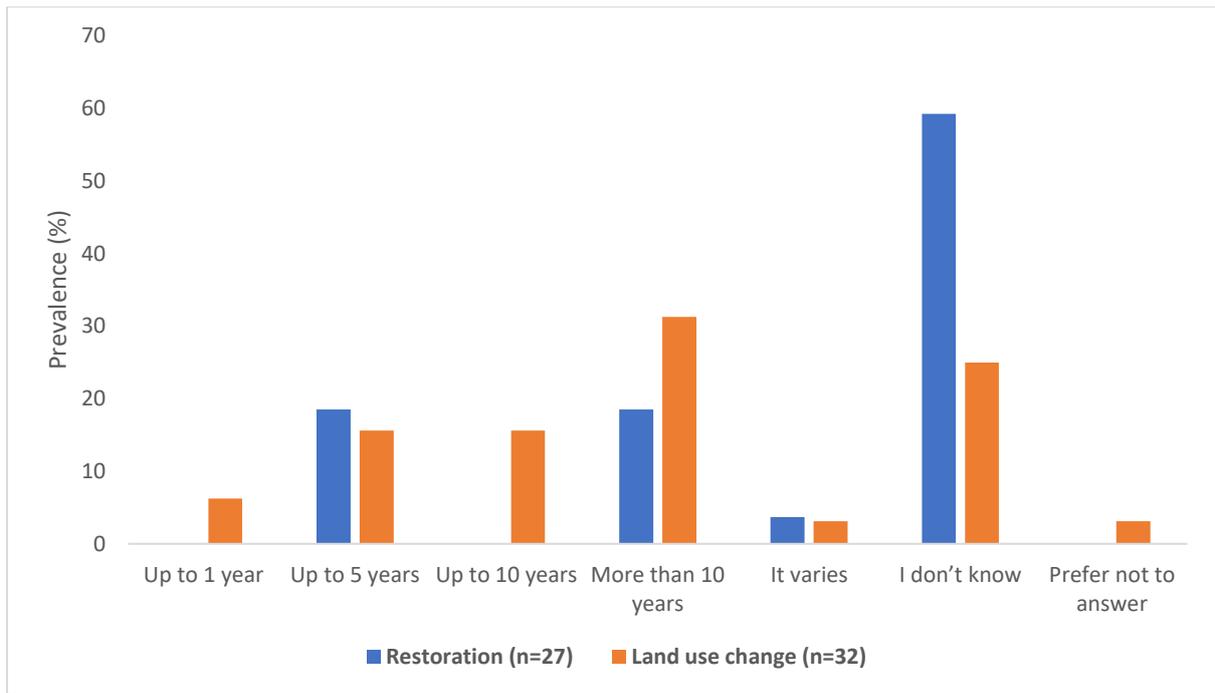
**FIGURE 2. PERCEIVED LIKELIHOOD OF POSITIVE (A) OR NEGATIVE (B) EFFECTS OF LAND USE CHANGE OR RESTORATION ON ZOOONOTIC DISEASE TRANSMISSION IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH. NEGATIVE EFFECT: DISEASE TRANSMISSION RISK INCREASES WITH LAND USE CHANGE/RESTORATION. POSITIVE EFFECT: DISEASE TRANSMISSION RISK DECREASES WITH LAND USE CHANGE/RESTORATION.**

Although 15% of restoration experts perceived that the potential negative consequences of restoration on zoonotic disease transmission in their study systems would be major or severe, this was generally seen as a risk with moderate or low negative consequences (Fig. 3). Conversely, the negative consequences of land use change were perceived as much more impactful. Around one third of restoration experts were either unsure or noted that these impacts vary (e.g. depending on specific disease, scale, process). For example, this was illustrated by a restoration expert: *“a fire-dependent forest ecosystem that is effectively managed on a 5-year burn schedule has been shown to lower tick-borne disease risk, while restoration of former agricultural lands to forest via succession increases tick-borne disease risk.”*

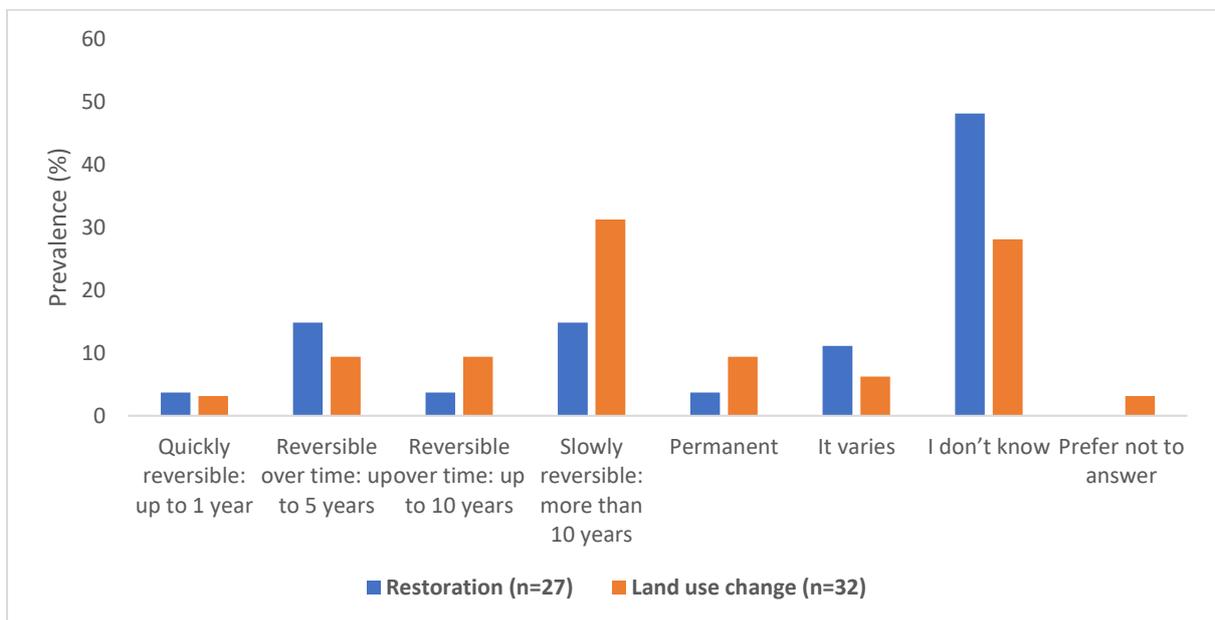


**FIGURE 3. PERCEIVED LEVEL OF POTENTIAL NEGATIVE CONSEQUENCES OF LAND USE CHANGE OR RESTORATION ON ZOOONOTIC DISEASE TRANSMISSION IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH.**

The duration of these potential negative consequences is particularly uncertain, with 59% of restoration experts unsure (Fig. 4). Nevertheless, 19% of restoration experts and 31% of land use change experts perceived that these might last more than 10 years, suggesting potential long-term impacts. Similarly, experts were generally unsure about the reversibility of these negative consequences (Fig. 5), although land use change impacts apparently were considered to be more slowly reversible than those of restoration.

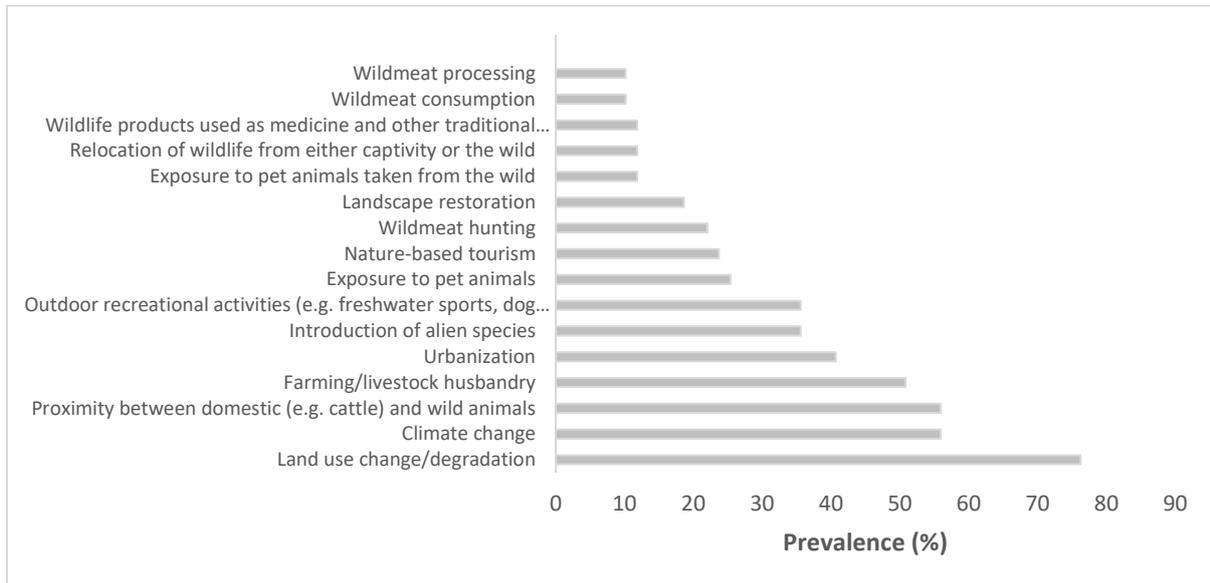


**FIGURE 4. PERCEIVED DURATION OF POTENTIAL NEGATIVE CONSEQUENCES OF LAND USE CHANGE OR RESTORATION ON ZOOONOTIC DISEASE TRANSMISSION IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH. DURATION REFERS TO PERIOD AFTER LAND USE CHANGE/RESTORATION.**



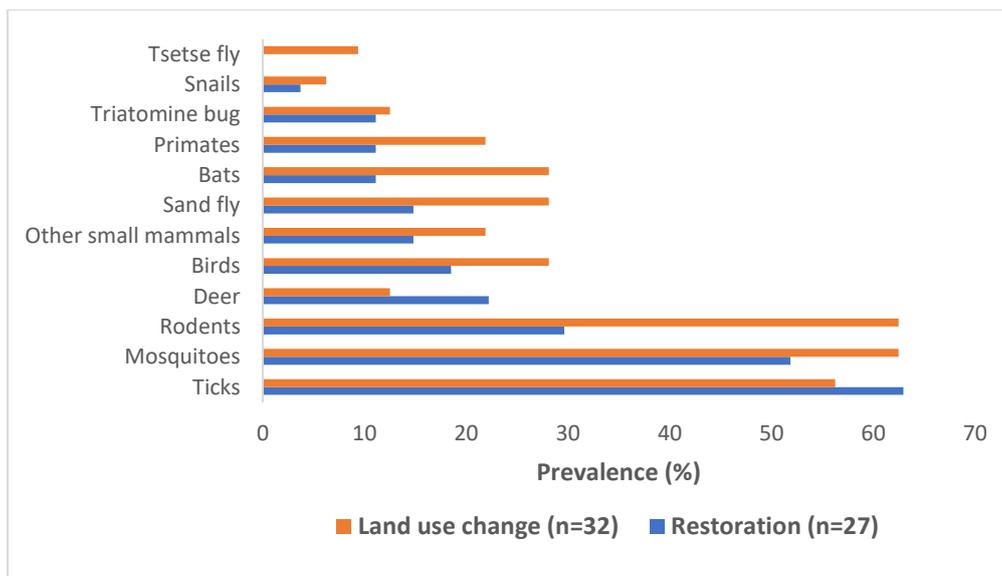
**FIGURE 5. PERCEIVED REVERSIBILITY OF POTENTIAL NEGATIVE CONSEQUENCES OF LAND USE CHANGE OR RESTORATION ON ZOOONOTIC DISEASE TRANSMISSION IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH.**

Of the 59 participants, 76% identified land use change and/or degradation as a key anthropogenic activity and/or process that facilitate, or could facilitate, the transmission of zoonotic diseases in their study systems (Fig. 6). Other issues commonly identified included: climate change; proximity between domestic animals (e.g. cattle) and wild animals; and farming/livestock husbandry (each mentioned by more than 50% of participants). Landscape restoration was mentioned by 19% of participants.



**FIGURE 6. PREVALENCE OF KEY ANTHROPOGENIC ACTIVITY AND/OR PROCESS THAT POTENTIALLY FACILITATE THE TRANSMISSION OF ZOOLOGIC DISEASES IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH.**

Ticks, mosquitoes and rodents were perceived as the most common vectors linked to potential negative effects (i.e. disease transmission risk increasing with land use change/restoration) in their study systems (Fig. 7). Others added by participants to the pre-defined list shown in Fig. 7 included: livestock, fleas and chigger mites (each mentioned by one participant).

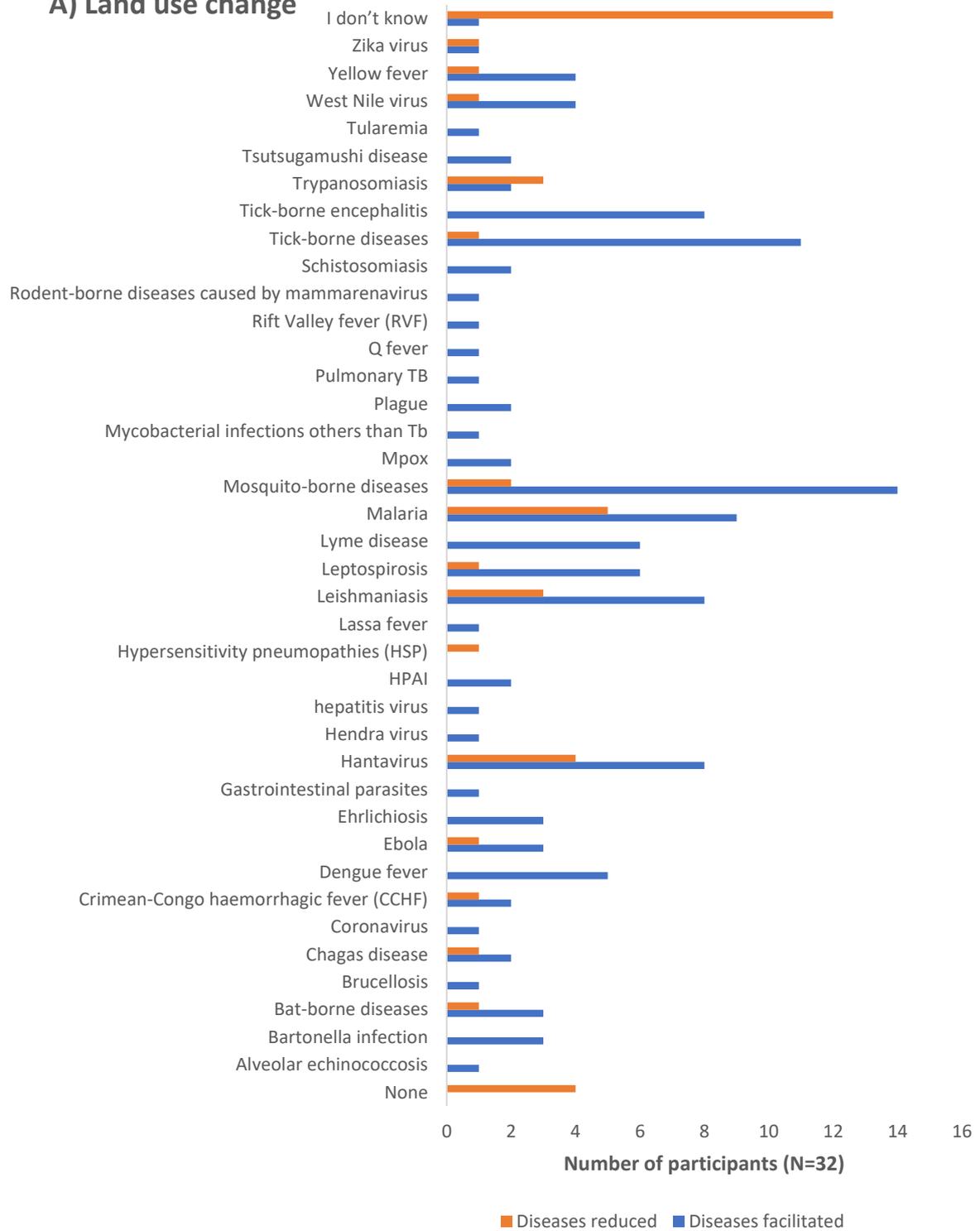


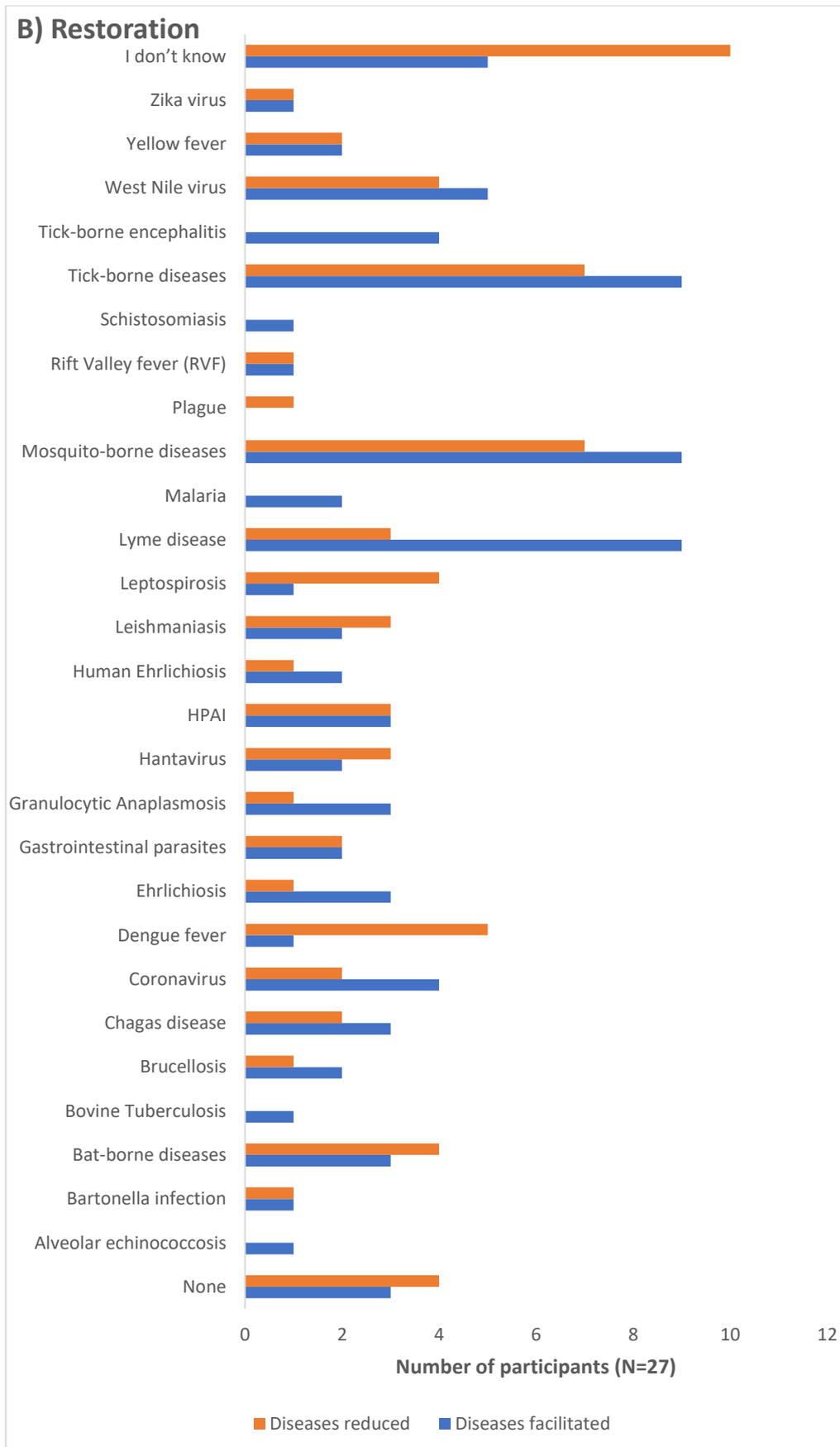
**FIGURE 7. VECTORS LINKED TO POTENTIAL NEGATIVE EFFECTS (I.E. DISEASE TRANSMISSION RISK INCREASING WITH LAND USE CHANGE/RESTORATION) IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH.**

Overall, land use change is generally perceived as a facilitator of zoonotic diseases, with disease reduction mentioned only occasionally (Fig. 8A). Among the 32 LUC experts, 97% mentioned at least one disease facilitated by land use change in their study systems, with a total of 36 types of disease being identified as being facilitated. Nevertheless, only 13% of the LUC experts mentioned that none were reduced as a result of land use change, and 38% were unsure.

Meanwhile, the responses were more varied in the restoration study systems, where restoration apparently acts as both a facilitator and a barrier to disease (Fig. 8B). Seventy per cent of the 27 “restoration experts” identified at least one zoonotic disease facilitated by restoration in their study systems, while 48% identified at least one disease that was reduced by restoration. Additionally, 15% of them stated that no diseases were reduced due to restoration in their study systems, while 11% stated that no diseases were facilitated by restoration. While most diseases were mentioned as being both facilitated and reduced in restoration systems, alveolar echinococcosis, bovine tuberculosis, malaria, schistosomiasis and tick-borne encephalitis were only mentioned as being facilitated by restoration. In addition, Lyme disease was considerably more frequently mentioned as being facilitated than reduced by restoration.

### A) Land use change



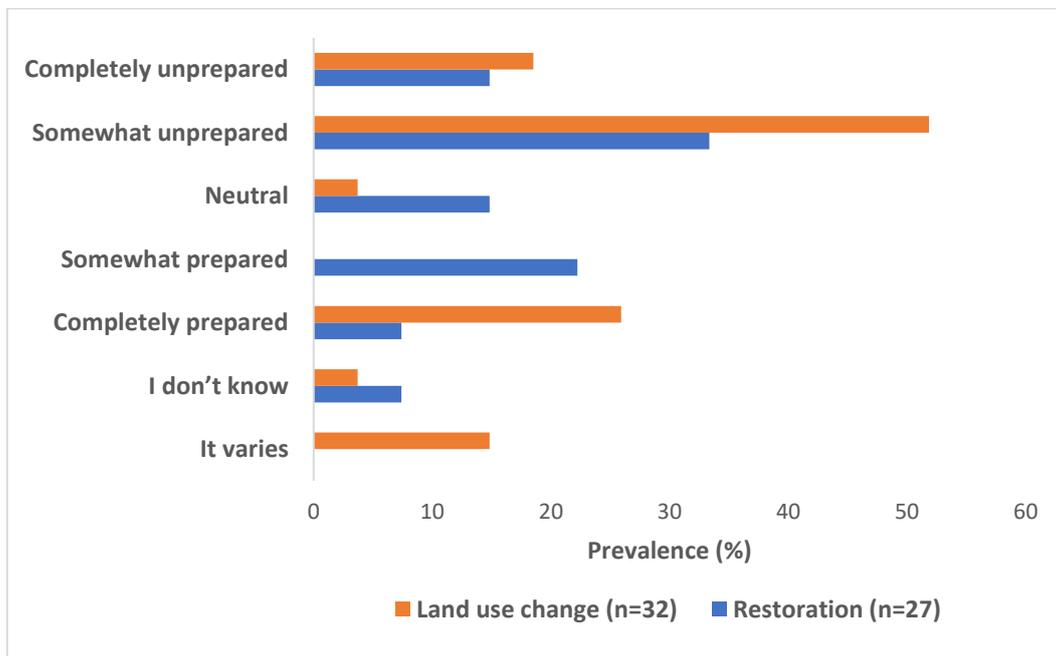


**FIGURE 8. OCCURRENCE OF DISEASE REDUCTION OR FACILITATION DUE TO LAND USE CHANGE (A) OR RESTORATION (B) IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH.**

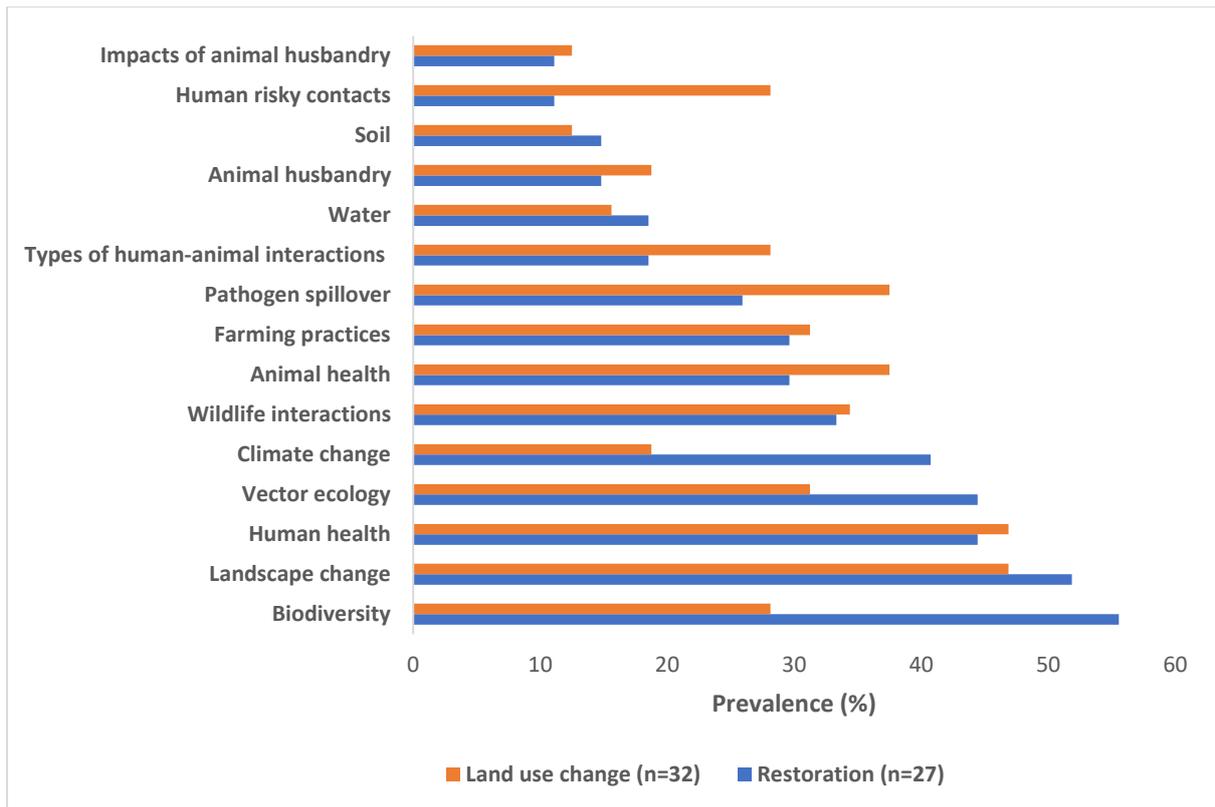
### 4.3 Preparedness and indicators for surveillance

Around half of the expert participants working in restoration initiatives perceived a general level of unpreparedness to cope with the transmission of zoonotic diseases in their study systems. This prevalence was even higher among experts working on land use change initiatives (around 70%; Fig. 9). Nevertheless, around 26% of those working on land use change initiatives perceived a very high level of preparedness ('completely prepared'), suggesting contrasting scenarios. When identifying the key factors limiting this preparedness, most participants focused on issues such as weak governance and coordination, insufficient funding and surveillance capacity, low awareness and knowledge, and the poor integration of zoonotic risk into land use and restoration planning, particularly at community and implementation levels.

When considering multiple components of the human–animal–environment interface that should be considered while designing surveillance for zoonotic diseases (adapted from Sharan et al., 2023), biodiversity was the most commonly mentioned in monitoring initiatives related to restoration (Fig. 10). This was followed by landscape change, human health, vector ecology and climate change (all mentioned by more than 40% of restoration experts). Some components, such as human risky contacts, types of human-animal interactions and pathogen spillover, seem to receive more attention in projects related to land use change than in restoration. Conversely, biodiversity, vector ecology and climate change seems to receive more attention in restoration projects. In addition, two participants mentioned that none of these were monitored.



**FIGURE 9. PREVALENCE (%) OF PERCEIVED LEVELS OF PREPAREDNESS TO COPE WITH ZOOONOTIC DISEASE TRANSMISSION IN INITIATIVES RELATED TO LAND USE CHANGE OR RESTORATION IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH.**



**FIGURE 10. PREVALENCE (%) OF MONITORING OF MULTIPLE COMPONENTS OF THE HUMAN–ANIMAL–ENVIRONMENT INTERFACE THAT SHOULD BE CONSIDERED WHILE DESIGNING SURVEILLANCE FOR ZOOBOTIC DISEASES (ADAPTED FROM SHARAN ET AL., 2023) IN INITIATIVES RELATED TO LAND USE CHANGE OR RESTORATION IN THE STUDY SYSTEMS WITH WHICH THE 59 EXPERT PARTICIPANTS ARE MOST FAMILIAR WITH.**

#### 4.4. Priority policy recommendations

The following main policy recommendations were identified based on experts’ own recommendations:

- integrate zoonotic disease risk into land-use and restoration policy;
- strengthen surveillance, monitoring, and early warning systems;
- institutionalise and operationalise the “One Health” approach;
- invest in public health, veterinary, and scientific capacity;
- promote community engagement, equity, and risk communication;
- reduce human–wildlife–vector contact through planning and design;
- align restoration, conservation, climate, and health agendas;
- improve governance, regulation, and accountability;
- incentivise sustainable and disease-reducing land management.

## 5. Conclusion and Recommendations

Land use change is consistently perceived to increase zoonotic disease transmission risk, while the effects of landscape restoration are more variable and context-dependent. According to the participant experts, restoration can both reduce and facilitate zoonotic diseases, though its negative impacts are generally considered lower and more uncertain than those of land use change. Overall preparedness to manage zoonotic risks remains inadequate, constrained by weak governance, limited surveillance capacity, and poor integration of health considerations into land-use and restoration planning. Experts strongly emphasize the need to embed zoonotic risk assessment within restoration and land-use policy through a mandatory One Health approach, supported by long-term surveillance, cross-sector coordination, and community engagement.

Given the key risks and uncertainties identified in this report, we call for the:

- integration of zoonotic disease risk assessment into land-use change and landscape restoration policies, plans, and funding criteria;
- institutionalization of the One Health approach across environment, agriculture, and health sectors through formal coordination mechanisms and shared accountability frameworks;
- establishment and funding of long-term, integrated surveillance systems that monitor biodiversity, wildlife, livestock, vectors, and human health in areas affected by land use change and restoration;
- requirement of risk-sensitive design and implementation of restoration projects, particularly during early phases, to minimise human–wildlife–livestock contact and potential spillover events;
- strengthening of governance and regulatory capacity by clarifying institutional roles, improving inter-sectoral coordination, and embedding zoonotic risk prevention in decision-making processes;
- increased sustained investment in public health, veterinary services, and scientific infrastructure, prioritising regions with high land-use change pressure and low preparedness;
- meaningful community engagement and risk communication, supporting equitable participation, local knowledge integration, and trust-building in restoration and land-use initiatives; and
- promotion of adaptive, context-specific land management and restoration practices, recognising that zoonotic outcomes vary by ecosystem, pathogen, and scale.

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## 7. Annex

### Recruitment email

SUBJECT: Participation kindly requested in research on the impact of land use change and landscape restoration on zoonotic disease transmission risks

Dear [NAME],

I hope this email finds you well. My name is Dr Ana Nuno and I am a researcher at the Interdisciplinary Centre of Social Sciences, NOVA University Lisbon, Portugal. I am reaching out to you to kindly request your participation in our online research survey, which aims to gather valuable insights on expert knowledge on the impact of land use change and landscape restoration on zoonotic disease transmission risks. This research is being done as part of RESTOREID (<https://restoreid.europamedia.org/>) - an EU-funded project dedicated to understanding and enhancing the relationship between nature restoration, biodiversity, and disease prevention.

You have been selected to participate as you: are listed as lead or corresponding author on a peer-reviewed publication on impacts of landscape restoration and degradation on disease and human-wildlife interactions; contributed as a study participant in the study done by Ekliptse's Expert Working Group on biodiversity and pandemics (Jagadesh et al. 2023); or were nominated by another expert taking part in our study. Your responses will play a significant role in shaping the outcomes of this study and I truly value your input and time. We estimate it will take approximately 20 minutes to complete this survey.

Please answer the survey here: [Survey Link].

Around a month after filling in this online survey, you will be provided with a summary of key findings and be asked to provide a second round of input. While you are welcome to only take part in the initial survey, full participation should be particularly interesting given your expertise in this field. Although you will be asked to provide your email contact so that the summary of key findings can be shared with you, I assure you that your anonymity will be strictly maintained. No one involved in the study will be made aware of the response or opinion of any individual panelist.

Please note that your involvement in this survey is completely voluntary, and you are free to withdraw at any point without any obligation before survey submission.

If you decide to participate, please complete the survey within the next three weeks - by [DATE].

If you have any questions or concerns regarding the survey or its content, feel free to contact me at [ananuno@fcsh.unl.pt](mailto:ananuno@fcsh.unl.pt).

Thank you again for considering this request, and I look forward to your participation.

Kind regards,

Ana Nuno, PhD

## Information sheet and consent form

### Expert elicitation on the impact of land use change and landscape restoration on zoonotic disease transmission risks

You are being invited to take part in an academic research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take the time to read the following information carefully.

#### Purpose of the research

The overall purpose of the research is to understand trends and impacts of land use change and restoration on zoonotic disease transmission risks at regional or national levels. This research is being done as part of RESTOREID - an EU-funded project dedicated to understanding and enhancing the relationship between nature restoration, biodiversity, and disease prevention.

#### Who is doing this research?

The lead researcher is Dr Ana Nuno, who is based at the Interdisciplinary Centre of Social Sciences at NOVA University in Lisbon, Portugal. Other people involved in this study include: researchers from the University of Stirling in the UK - Dr Adam Fell, Dr Brad Duthie, Prof Nils Bunnefeld; researchers from the Institut de Recherche pour le Développement (the French National Research Institute for Sustainable Development) - Dr Almudena Mari Sáez and Dr Simon Marijsse; and research consultant Dr Soushieta Jagadesh.

#### Ethical review of this research

This study has been reviewed by NOVA FCSH's Ethics Committee and received a favourable review. The review reference is CE-NOVA\_FCSH\_2025-042. The Data Protection Office may be contacted by emailing [dpo@unl.pt](mailto:dpo@unl.pt).

#### Procedures of this study

We estimate it will take approximately 20 minutes to complete this survey. You will be asked to complete questions relating to your expert knowledge on the impact of land use change and landscape restoration on zoonotic disease transmission risks. You have been selected to participate as you: are listed as lead or corresponding author on a peer-reviewed publication on impacts of landscape restoration and degradation on disease and human-wildlife interactions; contributed as a study participant in the study done by Eclipse's Expert Working Group on biodiversity and pandemics (Jagadesh et al. 2023); or were nominated by another expert taking part in our study.

This study uses the Delphi survey technique. If you agree to take part, you will be provided with a summary of key findings and then asked to provide a second round of input around a month after filling in this online survey. While you are welcome to take part in only the initial survey, full participation should be particularly interesting given your expertise in this field.

#### Benefits and risks of taking part

There is unlikely to be any direct or personal benefit to you in taking part. There may be some benefit to society; but this cannot be assured at the start of the research project. There are no risks to taking part in this research greater than what you may encounter on a daily basis in your normal life. If you feel any discomfort or doubt about taking part you can stop at any time before completing the survey.

#### Voluntary participation and your right to withdraw

Your participation in this study is entirely voluntary. You are under no obligation to take part and you may stop at any time. If you stop before completing the survey your information will not be saved and you will not have completed the survey. Withdrawal after participation is only possible in case you decide to provide your contact details; alternatively, once submitted, your responses will not be identifiable to the researcher to enable removal from the data set.

#### Anonymity

The survey referrer will not automatically provide your name and contact details to the researcher. Although you will be asked to provide your email address so that the summary of key findings can be shared with you, rest assured that your anonymity will be strictly maintained. No one involved in the study will be made aware of any individual panellist's response or opinion. If you would prefer not to provide your contact details, I will not be able to get in touch with you for follow-up studies or send you a summary of the key findings.

#### The Results

Results will be published or presented in academic papers and presentations. If you wish to be updated about the results of this study please email Ana Nuno at [ananuno@fcsh.unl.pt](mailto:ananuno@fcsh.unl.pt).

#### Consent:

- I have read and understand the information provided above.
- I understand that my participation is voluntary.
- I understand that I may withdraw and stop participating at any time during the survey.
- I understand that there will be no negative consequences for withdrawal.

**Survey on the impact of land use change and landscape restoration on zoonotic disease transmission risks**

**Section A. Your professional experience**

1. Please indicate the type(s) of organization(s) you currently work for (tick all that apply):
  - a) University/research institute
  - b) Environmental non-governmental organization
  - c) Non-governmental organization related to social issues (including human health)
  - d) Governmental agency
  - e) Consultancy
  - f) Other. Please specify: \_\_\_\_\_
  - g) Prefer not to answer
  
2. What best describes your role within your organization(s)? Tick all that apply:
  - a) Program coordination
  - b) Technical ecological work
  - c) Technical social work
  - d) Scientific research
  - e) Advocacy
  - f) Policy making
  - g) Other. Please specify: \_\_\_\_\_
  - h) Prefer not to answer
  
3. At what geographic scale do you mainly work at? Tick one option:
  - a) International (i.e. involving multiple countries)
  - b) National (i.e. at the scale of a single country)
  - c) Regional (e.g. related to specific region/district/state)
  - d) Local (e.g. related to specific community/ies)
  - e) Prefer not to answer
  
4. Please state the number of years of your professional experience in issues related to land use change, landscape restoration and/or zoonotic disease transmission risks:  
\_\_\_\_\_
  
5. Do you currently work, or have you worked, in research or applied projects related to landscape restoration? *Yes/No/Prefer not to answer*
  
6. Do you currently work, or have you worked, in research or applied projects related to zoonotic disease transmission? *Yes/No/Prefer not to answer*
  
7. Briefly describe your work regarding land use change, landscape restoration and/or zoonotic disease transmission risks: \_\_\_\_\_

## Section B. Prevalence, causes, impacts/consequences and risk severity of land use change or restoration on zoonotic disease transmission

[If the respondent answered YES to Q5 in section A: all text below should refer to “restoration”. Otherwise, it should refer to “land use change”.]

This section will aim to assess prevalence, causes, impacts/consequences and risk severity of land use change/restoration on zoonotic disease transmission. Please focus on a specific land use change/restoration area/study system that you are more familiar with.

1. What geographical area are you most familiar with in terms of land use change/restoration and/or zoonotic disease transmission? Ideally, please indicate ONE country only (but if you generally work at broader levels, please add that information). Please note that all following questions in this section will apply to this geographical area. \_\_\_\_\_
2. What is the approximate size of the land use change/restoration area within the case study/area where your work is based? \_\_\_\_\_
3. What is the approximate human population size within the case study/area where your work is based? \_\_\_\_\_
4. Please select the designation that best describes the biome underpinning your case study/area where your work is based [terminology from IUCN Global Ecosystem Typology 2.0]:
  - a) Terrestrial Realm [If selected, choose one from:]
    - i. Tropical-subtropical forests
    - ii. Temperate-boreal forests & woodlands
    - iii. Shrublands & shrubby woodlands
    - iv. Savannas and grasslands
    - v. Deserts and semi-deserts
    - vi. Polar-alpine
    - vii. Intensive land-use systems
  - b) Subterranean Realm [If selected, choose one from:]
    - i. Subterranean lithic systems
    - ii. Anthropogenic subterranean voids
    - iii. Subterranean freshwaters
    - iv. Anthropogenic subterranean freshwaters
    - v. Subterranean tidal systems
  - c) Freshwater Terrestrial Realm [If selected, choose one from:]
    - i. Palustrine wetlands
  - d) Freshwater Realm [If selected, choose one from:]
    - i. Rivers and streams
    - ii. Lakes
    - iii. Artificial fresh waters
  - e) Freshwater Marine Realm [If selected, choose one from:]
    - i. Semi-confined transitional waters
  - f) Marine Realm [If selected, choose one from:]
    - i. Marine shelves
    - ii. Pelagic ocean waters
    - iii. Deep sea floors

- iv. Anthropogenic marine systems
- g) Marine Terrestrial Realm [If selected, choose one from:]
  - i. Shoreline systems
  - ii. Supralittoral coastal systems
  - iii. Anthropogenic shorelines
- h) Freshwater Marine Terrestrial Realm [If selected, choose one from:]
  - i. Brackish tidal systems (including mangroves)
- i) Prefer not to answer

5. Please select the specific anthropogenic activities or environmental issues being targeted/addressed in your case study/area where your work is based [Multiple options allowed; terminology adapted from the International Union for the Conservation of Nature (IUCN) Red List - Conservation Measures Partnership (CMP) Classification of Direct Threats to the Conservation of Ecosystems and Species 4.0.]. Tick all that apply:

- a) Residential, commercial & recreation areas
- b) Agriculture & aquaculture (incl. non-timber crops, plantations, farming, ranching & herding)
- c) Energy production & mining (incl. renewables)
- d) Transportation, service & security corridors (incl. fencing and walls)
- e) Biological resource use & control (incl. hunting, gathering, logging, fishing, phytotherapy, controlling species)
- f) Human intrusions & disturbances (i.e. activities that may alter, destroy and disturb habitats and species associated with nonconsumptive uses of biological resources, including e.g. recreation, war, civil unrest and pilgrimages)
- g) Natural system management & modifications (inc. managing fires, dams, weather)
- h) Invasive & other problematic species, genes & pathogens
- i) Pollution (domestic, commercial, agricultural)
- j) Natural disasters (inc. geological events and severe weather)
- k) Climate change
- l) Community development issues (e.g. educational, cultural, economic, social and environmental wellbeing of communities, resettlement of indigenous peoples)
- m) Other. Please specify: \_\_\_\_\_
- n) Prefer not to answer

5.1. [If respondent answered YES to Q5 in section A:] Briefly describe the goals and objectives of the restoration project/initiative within the case study/area where your work is based (e.g. timeframe, type of interventions, taxa). \_\_\_\_\_

5.2. [If respondent answered NO to Q5 in section A:] Briefly describe the type of land use change within the case study/area where your work is based (e.g. timeframe, drivers, type of interventions, taxa). \_\_\_\_\_

6. Based on your expertise, what is the direction of effects of land use change/restoration on zoonotic disease transmission in your case study/area where your work is based?
- Negative effect (disease transmission risk increases with land use change/restoration)
  - Neutral/ no effect
  - Positive effect (disease transmission risk decreases with land use change/restoration)
  - It varies. Please specify: \_\_\_\_\_
  - I don't know
  - Prefer not to answer
7. Based on your expertise, what is the likelihood of positive effects (disease transmission risk decreases with land use change/restoration) in your case study/area where your work is based?
- Very unlikely to occur
  - Not expected to occur
  - Likely – could occur
  - Known to occur - almost certain
  - Common occurrence
  - I don't know
  - Prefer not to answer
8. Based on your expertise, what is the likelihood of negative effects (disease transmission risk increases with land use change/restoration) in your case study/area where your work is based?
- Very unlikely to occur
  - Not expected to occur
  - Likely – could occur
  - Known to occur - almost certain
  - Common occurrence
  - I don't know
  - Prefer not to answer
9. Based on your expertise, what is the level of potential negative consequences of land use change/restoration on zoonotic disease transmission in your case study/area where your work is based?
- Negligible
  - Minor
  - Medium
  - Major
  - Severe
  - It varies. Please specify: \_\_\_\_\_
  - I don't know

- h) Prefer not to answer
10. Based on your expertise, what is the duration of potential negative consequences of land use change/restoration on zoonotic disease transmission in your case study/area where your work is based?
- a) Up to 1 year after land use change/restoration
  - b) Up to 5 years after land use change/restoration
  - c) Up to 10 years after land use change/restoration
  - d) More than 10 years after land use change/restoration
  - e) It varies. Please specify: \_\_\_\_\_
  - f) I don't know
  - g) Prefer not to answer
11. Based on your expertise, what is the reversibility of potential negative consequences of land use change/restoration on zoonotic disease transmission in your case study/area where your work is based?
- a) Quickly reversible: up to 1 year after land use change/restoration
  - b) Reversible over time: up to 5 years after land use change/restoration
  - c) Reversible over time: up to 10 years after land use change/restoration
  - d) Slowly reversible: more than 10 years after land use change/restoration
  - e) Permanent
  - f) It varies. Please specify: \_\_\_\_\_
  - g) I don't know
  - h) Prefer not to answer
12. What type of anthropogenic activities and/or processes (potentially) facilitate zoonotic disease transmission in your case study/area where your work is based? [Multiple options allowed]
- a) None
  - b) Climate change
  - c) Exposure to pet animals taken from the wild
  - d) Exposure to pet animals
  - e) Farming/livestock husbandry
  - f) Introduction of alien species
  - g) Land use change/degradation
  - h) Landscape restoration
  - i) Nature-based tourism
  - j) Outdoor recreational activities (e.g. freshwater sports, dog walking, trekking)
  - k) Proximity between domestic (e.g. cattle) and wild animals
  - l) Relocation of wildlife from either captivity or the wild
  - m) Wildlife products used as medicine and other traditional practices
  - n) Wildmeat consumption
  - o) Wildmeat hunting
  - p) Wildmeat processing

- q) Urbanization
- r) Other. Please specify: \_\_\_\_\_
- s) I don't know
- t) Prefer not to answer

13. What types of vectors are linked to negative effects (i.e. disease transmission risk increases with land use change/restoration) in your case study/area where your work is based?

[Multiple options allowed]

- a) None
- b) Bats
- c) Birds
- d) Deer
- e) Mosquitos
- f) Primates
- g) Rodents
- h) Other small mammals
- i) Sand fly
- j) Snails
- k) Ticks
- l) Triatomine bug
- m) Tsetse fly
- n) Other. Please specify: \_\_\_\_\_
- o) I don't know
- p) Prefer not to answer

14. What type of diseases are facilitated by land use change/restoration in your case study/area where your work is based? [Multiple options allowed]

- |                               |                               |
|-------------------------------|-------------------------------|
| a) None                       | r) Lyme disease               |
| b) Alveolar echinococcosis    | s) Malaria                    |
| c) Bartonella infection       | t) Mosquito-borne diseases    |
| d) Bat-borne diseases         | u) Mpox                       |
| e) Chagas disease             | v) Nipah virus                |
| f) Coronavirus                | w) Plague                     |
| g) Dengue fever               | x) Pulmonary TB               |
| h) Ebola                      | y) Ross River virus           |
| i) Ehrlichiosis               | z) Schistosomiasis            |
| j) Gastrointestinal parasites | aa) Thrombocytopenia syndrome |
| k) Granulocytic Anaplasmosis  | bb) Tick-borne diseases       |
| l) Hantavirus                 | cc) Tick-borne encephalitis   |
| m) Hendra virus               | dd) Trypanosomiasis           |
| n) HPAI                       | ee) Tsutsugamushi disease     |
| o) Human Ehrlichiosis         | ff) West Nile virus           |
| p) Leishmaniasis              | gg) Yellow fever              |
| q) Leptospirosis              | hh) Zika virus                |

ii) Other. Please specify: \_\_\_\_\_

kk) Prefer not to answer

jj) I don't know

15. What type of diseases are reduced by land use change/restoration in your case study/area where your work is based? [Multiple options allowed]

- a) None
- b) Alveolar echinococcosis
- c) Bartonella infection
- d) Bat-borne diseases
- e) Chagas disease
- f) Coronavirus
- g) Dengue fever
- h) Ebola
- i) Ehrlichiosis
- j) Gastrointestinal parasites
- k) Granulocytic Anaplasmosis
- l) Hantavirus
- m) Hendra virus
- n) HPAI
- o) Human Ehrlichiosis
- p) Leishmaniasis
- q) Leptospirosis
- r) Lyme disease
- s) Malaria
- t) Mosquito-borne diseases
- u) Mpox
- v) Nipah virus
- w) Plague
- x) Pulmonary TB
- y) Ross River virus
- z) Schistosomiasis
- aa) Thrombocytopenia syndrome
- bb) Tick-borne diseases
- cc) Tick-borne encephalitis
- dd) Trypanosomiasis
- ee) Tsutsugamushi disease
- ff) West Nile virus
- gg) Yellow fever
- hh) Zika virus
- ii) Other. Please specify: \_\_\_\_\_
- jj) I don't know
- kk) Prefer not to answer

### Section C. Preparedness to cope with zoonotic disease transmission risks and priorities for wildlife pathogens surveillance

This section will aim to assess preparedness to cope with zoonotic disease transmission risks and determine priorities for wildlife pathogens surveillance. Please focus on the land use change/restoration area/study system that you are more familiar with and have referred to in the previous section.

1. Based on your experience, what is the overall level of preparedness to cope with zoonotic disease transmission in initiatives related to land use change/restoration in your case study/area where your work is based?
  - a) Completely unprepared
  - b) Somewhat unprepared
  - c) Neutral
  - d) Somewhat prepared
  - e) Completely prepared
  - f) It varies. Please specify: \_\_\_\_\_
  - g) I don't know
  - h) Prefer not to answer
  
2. To explain the level of the overall level of preparedness scored above, what factors are more important in explaining the limitations of this preparedness? \_\_\_\_\_
3. To explain the level of the overall level of preparedness scored above, what factors are more important in explaining the strengths of this preparedness? \_\_\_\_\_
4. What components of the human–animal–environment interface (adapted from *Sharan et al. 2023*) are currently monitored in initiatives related to land use change/restoration in your case study/area where your work is based?
  - a) None
  - b) Human health
  - c) Human risky contacts
  - d) Climate change
  - e) Landscape change
  - f) Types of human-animal interactions
  - g) Pathogen spillover
  - h) Animal health
  - i) Farming practices
  - j) Wildlife interactions
  - k) Animal husbandry
  - l) Impacts of animal husbandry
  - m) Vector ecology
  - n) Water
  - o) Soil

- p) Biodiversity
- q) Other. Please specify: \_\_\_\_\_
- r) I don't know
- s) Prefer not to answer

5. Based on your experience, what should be the key indicators used to identify zoonotic disease transmission risks in initiatives related to land use change/restoration in your case study/area where your work is based? \_\_\_\_\_

#### Section D. Research needs and recommendations

1. In your point of view, what are the three most important research needs related to the impact of land use change and landscape restoration on zoonotic disease transmission risks?

- 1. \_\_\_\_\_
- 2. \_\_\_\_\_
- 3. \_\_\_\_\_

2. In your point of view, what are the three most important policy recommendations related to the impact of land use change and landscape restoration on zoonotic disease transmission risks?

- 1. \_\_\_\_\_
- 2. \_\_\_\_\_
- 3. \_\_\_\_\_

#### Section E. Your demographics

1. How old are you?

- a) 18-24
- b) 25-34
- c) 35-44
- d) 45-54
- e) 55-64
- f) 65 or more
- g) Prefer not to answer

2. What is your gender identity?

- a) Woman
- b) Man
- c) Non-binary
- d) Self-describe. If you'd like to self-describe, please do so here: \_\_\_\_\_
- e) Prefer not to answer

3. What's your nationality? If you have more than one nationality, please choose the one you identify with the most

- dropdown list [including "Prefer not to answer"]

### Section F. End of survey

1. Please state below any comments or suggestions you may have about this research topic.

\_\_\_\_\_

2. Please suggest up to 3 other experts who we could invite for the survey (colleagues, peers or institutional representatives that may have relevant experience on the survey's topic). Please include their name, institution and email.

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_

3. This study uses the Delphi survey technique. Are you willing to take part in a second round of this survey, after being provided with a summary of key findings from the first round? *Yes/No*

[If yes:] Please provide your email contact: \_\_\_\_\_