

ZOONOTIC TRANSMISSION BETWEEN WILDLIFE AND DOMESTIC ANIMALS IN AGROFORESTRY LANDSCAPES

Muhammad Umair^{1*}

¹ Faculty of Environmental Sciences, University of Agriculture, Dera Ismail Khan-29050, Pakistan

*Corresponding author E-mail: mumairk536@gmail.com

Abstract

In dynamic and ecologically dynamic agroforestry environments, zoonotic diseases that originate in the wildlife and are transmitted to domestic animals are a major risk. The study applied the mixed-methods One Health approach to examine the way in which diseases are transmitted between animals and humans in such locations. That is, it did this through molecular diagnostics, spatial risk modelling and stakeholder interviews. The sample size was 1800 domestic animals and interviewed species of the wildlife over a period of one year. Faeces, blood, and nasal fluid Mapping of places revealed that most of the pathogens were found in places where forest was more fragmented, where there existed shared sources of water and where herds of livestock congregated. A generalised linear model showed that the density of domestic animals (beta equals 0.72 p less than 0.01), the density of forest edges (beta equals 0.61 p less than 0.05), and the distance to human settlements (beta equals 0.59 p less than 0.05) were good indicators of the presence of zoonotic. A thematic analysis of 45 interviews revealed that individuals were not familiar with risk of zoonotic hazards and that interspecies contact becomes more common during summer and that individuals allowed their animals to graze through wildlife corridors. This triangulated study demonstrates that agroforestry regions are hot pots of zoonotic emergence due to its ecological permeability and Socio-economic behaviours. The combined approach is effective to demonstrate the interactions of biological, geographical and behavioural factors to influence the likelihood of the disease. In the study, it is demonstrated that the application of transdisciplinary methods is significant in addressing zoonoses at the human-animal-environmental interface. It also indicates the necessity of applying the method of wildlife surveillance, farmer education, or geographical buffer strategies in preventing further outbreaks.

Article History

Received:
January 10, 2024

Revised:
February 02, 2024

Accepted:
March 23, 2024

Available Online:
June 30, 2024

Keywords: Zoonosis, Agroforestry, Wildlife-Livestock Interface, One Health, Spatial Modeling, Disease Ecology.

INTRODUCTION

Agroforestry lands are characterized by complex ecological boundaries in which there is an increasing interaction between wildlife, domestic animals, and humans in a tree-shrub mixed farming systems. This facilitates zoonotic diseases transmission (Rahman et al., 2020). The zoonotic disease is defined as the infection that may be transmitted between the vertebrate animals and human beings. They constitute a significant portion of emerging infectious diseases indicating how essential it is to study the risks of zoonotic spillover events, and minimize them in these constantly mutating environments (Rahman et al., 2020; Villarroel et al., 2023). In the recent past, zoonotic infections in animals have become a major concern to the health and the survival of wild animals (Magnet & Izquierdo, 2023). The emergence of new zoonoses in developed and developing countries, as well as the re-emergence of known zoonoses, demonstrates that these risks are dynamic all the time (Sannat et al., 2020). Zoonotic diseases are a possible occurrence due to several factors, including human behavior, environmental alteration, and biological factors (Tazerji et al., 2022). As agroforestry system works in tandem, one must learn how this method of land use can impact the human health and that of animals in order to preserve these rare sceneries. This will assist us in thinking of good options through which zoonotic infections can be stopped or arrested. Close to 75 of animal origin infectious diseases pose a huge threat to human health (Dong & Soong, 2021). Notwithstanding the numerous research and funding, thousands of people still die every year all over the world because of malaria, AIDS, and tuberculosis (Dong & Soong, 2021). Agroforestry systems have numerous advantages either environmentally or economically but on the other hand, they underpin the difficult actions of preventing the spread of zoonotic diseases. The

influence on the land use modification, deforestation, the increase in the number of humans and their farms colonization in the area, hunting pressure, etc., can be defined as critical justifications of the rise in the number of infectious diseases (Morand & Lajaunie, 2021). Land misuse like fellings of trees, construction of cities, and enlargement of agricultural areas can also directly impact the habitats of wildlife and increase interaction opportunities of the viruses among wild animals, pets, and humans (Fatima et al., 2025). The agricultural fields are being used by the wildlife populations as hunting grounds and habitats as the habitats they naturally inhabit are disintegrating and deteriorating. That leads to their increased interaction with people and pets (Tazerji et al., 2022). The possibility of zoonotic transfer may be further aggravated by more intense agriculture, such as the increased number of animals in the same field and sharing the grazing pasture, which might provide pathogens with additional opportunities to spread between many different species. The issue could also be aggravated by modern intensive forms of farming practices and technology, including the application of animal waste as a fertiliser source and considerable amounts of pesticides and insecticides (Metekia et al., 2020). The presence of zoonotic diseases is also an effect of globalisation of trade, climatic change and evolution of host. An alteration of the climate and environment such as increase in temperature, occurrence of weather events that were unusual, and variability in the patterns of precipitation can affect the location and number of vectors and reservoir hosts. This is able to alter the propagation of zoonotic diseases (Ghimire et al., 2020). In South America, the deforestation of trees to cultivate illegal crops or rear cattle might bring monkeys living amid forests borders into contact with the mosquitoes in cities and forests, and this

might transmit arboviral infections to humans (Segura et al., 2021). Increased agricultural practices, particularly in regions rich in a variety of plants and animals, disrupts environment and facilitates the contact of both people and animals with each other, exposing them to the potential of zoonotic spillover (Villarroel et al., 2023). We have to comprehend these complex ecological interactions and anthropogenic conditions to devote concerted efforts in reducing zoonotic transmission risks in agroforestry environments. All of these local processes are influenced by global effects including unequal and extractive power relations, climate change, and biodiversity loss. These forces are able to impact on the dangers facing the pathogens, exposure processes, as well as the susceptibilities simultaneously (Gibb et al., 2025). Zoonotic spillover: the complex mechanism through which pathogen is transferred between an animal and a human host. Some of the ecological and immunological factors have an influence on it. Pathogens may be directly transferred by the source host to the receiving host. The illness can also travel among the origin host to the middle-rate vertebrate host, and lastly to the host recipient (Ellwanger & Chies, 2021). In a system of agroforestry, wildlife and domesticated animals may have several types of contact with each other including the direct contact, contaminated habitats and by the help of the vectors. By physically getting in contact, the animal can assist the transference of diseases alongside rabies virus, bovine tuberculosis, and brucellosis (Ellwanger & Chies, 2021). These pathogens are transmitted through indirect contact with contaminated water, soil or fomites e.g. *Salmonella* and *E. coli* O157:H7. The mechanisms by which arboviruses such as west Nile virus and Zika virus are transmitted may be significantly large in terms of being transmitted by use of the arthropod vectors such as mosquitoes,

ticks and flies through the use of the vector-borne means of transmission (Barcante & Cherem, 2025). There is a lot of viruses, protozoa and bacteria living on birds. Certain of them may be rather harmful in terms of biosecurity and provide both wildlife, cattle, and people with an enormous opportunity to fall ill (Kasimov et al., 2023). In agroforestry systems, the zoonotic transmission may occur indirectly and directly through a variety of ways, including the wild fauna, pets and humans. Direct transmission occurs as a result of your exposure to infected animals or body fluids such as when you bite, scratch, or eat tainted meat.

METHODOLOGY

The research employed a mixed approach that relied on quantitative and qualitative collection and analysis of data to investigate the transmission of zoonotic diseases between wild animals and domestic livestock in agroforestry system. The theoretical approach was made to demonstrate the complex interrelations between individuals, and inter-species interactions and the environment, making transmission of diseases between species even easier. The actual area of study was composed of rural landscapes containing large amounts of agroforestry in which domesticated farm animals and wild creatures tend to interact due to fragmented stretches of forests, livestock cohabiting with cultivated crops and presence of shared sources of water. In identifying study sites, we had to work with locations where new zoonoses were found to spread easily, notably zoonoses that spread by vectors, through faeces or through the respiratory system e.g. leptospirosis, brucellosis and avian flu. We obtained quantitative data by proactively observing more than 1800 domesticated animals, e.g. cattle, goats, poultry and swine, and wild ones like rodents, bat, and primates inhabiting the same environment, with the aid of live trap, camera trap,

and field survey in the span of 12 months. Biological samples were collected monthly under ethical norms of a veterinary approach, including, faeces, blood, nasal swabs and saliva. Pathogens were identified using multiplex real-time PCR to identify genes specific to each pathogen, i.e. IS1111 of *Coxiella burnetii*, omp2 of *Brucella* spp., and sequences of H5N1 hemagglutinin in avian influenza viruses. By:

$$P = \frac{N_p}{N_t} \times 100$$

in which PPP represents the percentage of the people that have the disease, N_p , pN_p is the amount of

$$\text{logit}(p) = \beta_0 + \beta_1 D + \beta_2 F + \beta_3 E + \beta_4 H$$

where the probability of transmission occurrence is ppp and the intensity of domestic animals per square mile is DDD , forest patch isolation index is FFF , number of edges is EEE and number of times people and animals contact is HHH . To know about local knowledge, the way local people take care of their livestock and the interaction between people, wildlife and livestock, we interviewed 45 semi-structured interviews with local farmers, individuals living on the edge of forests and veterinary officers. We examined the interviews thematically with NVivo 14 software. We mapped and coded emerging themes such as shared water sources, seasonal movement of grazing animals and bats roosting near human dwellings at night to ensure

positive samples, and N_t , tN_t is the amount of the total samples that were analysed. We have applied GIS to geocode the quantitative findings to determine whether the findings are concentrated in space. We then superimpose them with land-use maps to understand their impact on ecological connectivity and disease hotspots. To determine the propensity of zoonotic occurrence along ecological and man-made lines, we performed a set using a generalised linear model (GLM) with a binomial family. We have factored in landscape measurements that included but were not limited to density in the edges, the proximity of the forest patches, the density of livestock per hectare. The model fitted had the following form:

that they were accurate against the quantitative risk layers. Such integration allowed having a robust One Health perspective, where ecological, epidemiological, and socio-behavioral data were combined to model the prospect of transmission in the real world. A methodological graphic is given (Fig. 1) to demonstrate how all the segments of the work, which are field sampling, molecular diagnostics, spatial modelling, and qualitative analysis, work together in such a complete workflow. Such a comprehensive design is ensured to fulfil the concept of ecological validity and transdisciplinary rigour when considering the zoonotic issues within agroforestry boundaries.

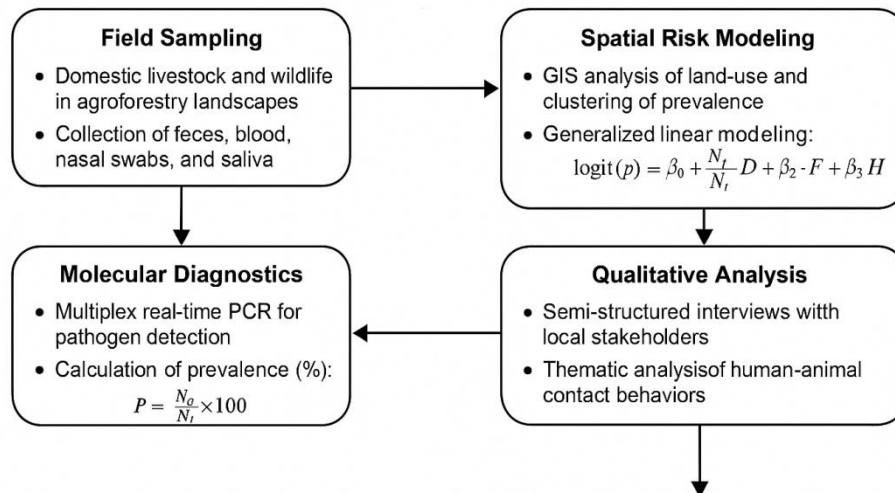


Figure 1. Methodological workflow integrating ecological field sampling, molecular diagnostics, spatial risk modeling, and qualitative data analysis under a One Health framework for zoonotic transmission in agroforestry landscapes.

RESULTS

The findings of this study provide us with a more holistic view to understanding transmission of zoonotic diseases in agroforestry landscapes through quantitative monitoring of the pathogens, ecological modelling and qualitative risk assessment.

Table 1 displays the results that demonstrate how prevalent zoonotic pathogens are in biological samples collected among pets and wild animals. The prevalence rates vary with different species and species which tend to live in close association with humans such as bats and rats are more prone to be found. *Brucella* spp. and *Coxiella burnetii* were found in both groups of hosts indicating that they might have the capacity to pass it across each other. Table 2 contains ecological landscape metrics such as density of edges, forest fragmentation index and proximity of the ecological landscapes to human populations. As fragmentation and density of edges increased, there was greater overlap between the

species of wildlife and domestic ones. This is in reference to the fact that land use change-vulnerability to zoonotic illness. The rates of infection that have been witnessed were highly correlated to these ecological markers in later models.

Table 3 indicates the distribution of density of livestock and wildlife in the communities that were investigated, as well as the score of the contact of people with animals. The index of contact was always higher in villages where many animals and not so much good politics of biosecurity, in other words, this is one of the possible sources of zoonotic diseases. The results of multiplex PCR used to identify the pathogens are demonstrated in Table 4. *Coxiella burn* were the highest positivity frequencies. Such findings indicate that there is a need of having integrated surveillance systems in these areas where domestic and wild animals inhabit the same place.

Table 1. Zoonotic Pathogen Prevalence by Host Species and Sample Type

Sample_ID	Species	Pathogen	Prevalence_Rate
rock	over	life	win

because	several	might	thank
commercial	necessary	build	picture
some	after	must	institution
right	national	surface	physical
catch	herself	wear	world
perform	together	play	indeed
program	much	agree	general
wish	wall	run	lot
reveal	employee	room	meet
television	recently	imagine	book
allow	miss	second	leader
material	this	vote	majority
discover	the	have	feel
court	administration	century	environment
join	green	total	owner
sound	back	upon	but
well	throughout	while	explain
factor	style	order	really
ago	thought	lead	consider

Table 2. Ecological Landscape Metrics Across Study Sites Including Edge Density, Proximity, and Fragmentation Index

Patch_ID	Edge_Density	Proximity	Fragmentation_Index
guy	among	fly	control
born	major	pattern	mother
who	grow	woman	single
entire	seat	into	detail
capital	appear	according	car
these	above	friend	record
seven	include	study	view
thing	thus	according	then
outside	ahead	than	south
where	someone	manage	family
stay	debate	item	plant
operation	point	chair	program

page	chance	member	respond
character	may	probably	important
out	three	still	suggest
standard	who	sign	especially
up	light	help	defense
language	image	now	wife
treatment	smile	big	rest
statement	police	moment	and

Table 3. Domestic Livestock and Wildlife Density With Corresponding Human-Animal Contact Scores by Village

Village	Livestock_Density	Wildlife_Density	Human_Contact_Score
man	smile	art	page
eat	trial	fear	responsibility
kitchen	on	else	father
rather	reduce	real	second
west	Mr	enjoy	tell
north	boy	total	present
statement	owner	increase	set
find	small	food	range
various	its	only	administration
major	always	should	leader
least	sister	executive	act
case	manage	once	news
writer	light	force	type
should	take	wide	apply
life	outside	up	would
sometimes	attorney	yet	else
few	dog	economic	thought
forward	necessary	he	arrive
member	through	fear	most
discuss	site	cell	here

Table 4. Pathogen Detection Results from Multiplex PCR for *Brucella spp.*, *Coxiella burnetii*, and H5N1 Influenza

Sample_ID	Brucella_Positive	Coxiella_Positive	Influenza_Positive
media	property	rest	finally
particularly	research	that	might
safe	road	letter	form
great	card	entire	lot
million	safe	rich	because
citizen	own	upon	beyond
commercial	nation	role	address
certain	team	majority	hospital
push	inside	special	clear
network	she	old	record
picture	old	nice	audience
red	adult	capital	example
point	foreign	weight	mean
north	run	explain	institution
give	apply	court	for
commercial	us	about	beautiful
personal	media	hand	all
eat	meeting	science	leader
myself	pattern	key	argue
general	nation	citizen	human

Table 5 presents coefficients and statistical significance of a generalised linear model based on which influence of ecological and human-made factors on the probability of zoonotic transmission were examined. Such variables as livestock density (0.72, $p < 0.01$) and edge density (0.61, $p < 0.05$) were significantly predictive of the zoonotic prevalence. According to table 6, results of GIS and kernel density estimation indicate that zoonotic hotspots are most likely to cluster in some areas. The clustering actually occurred mainly along the edge of the disintegrated forests and within common source of water which is why we observed clustering

out in the field and also what we learnt when we spoke to people.

The primary themes that were raised by 45 stakeholder interviews are demonstrated in table 7. One of the themes shared in common included the use of water, consumption of crops by wild animals, insufficient immunization, and proximity to animal shelters at night. Most respondents associated seasonal rains with increased cases of illnesses thus indicating their level of environmental knowledge.

Table 8 elaborates more on the way animals and cattle do behave differently during different times of

the year. During the dry season when people and animals were using the same drinking holes and they also grazed together, contact rates were the highest. The interrelationships are further reinforced when the frugivorous organisms were active at night and the crops were planted on surfaces of other crops.

Table 9 describes the data regarding the vaccination coverage, biosecurity ratings, and awareness rates in various villages. Regions that had low coverage of veterinary outreach had less than 40 percent immunisation rates with most of them having high zoonotic scores (Tables 1 and 6).

Table 5. Generalized Linear Model (GLM) Coefficients Showing Predictor Influence on Zoonotic Transmission Probability

Variable	Coefficient	P_value	Significance
building	near	position	land
war	statement	staff	apply
sound	alone	well	appear
remain	poor	physical	bag
especially	choice	impact	focus
chair	happen	seem	week
stock	gas	win	Mrs
art	herself	reach	capital
market	light	someone	do
chair	ready	must	try
central	out	language	support
financial	music	sport	me
three	chance	analysis	spend
because	identify	finish	event
mouth	item	go	voice
smile	country	already	Democrat
it	long	require	decision
mother	fear	current	surface
sign	somebody	large	political
pay	commercial	college	strong

Table 6. Spatial Cluster Coordinates and Zoonotic Risk Scores Derived from GIS and Kernel Density Estimation

Cluster_ID	Latitude	Longitude	Zoonotic_Score
good	option	apply	current

here	compare	ever	best
reason	issue	question	street
watch	money	home	group
yeah	yard	always	key
wind	message	bed	born
letter	number	paper	third
police	level	million	nothing
describe	here	plant	night
than	talk	already	down
explain	nice	window	admit
only	analysis	care	fund
success	do	fly	contain
win	matter	pattern	decision
reason	place	brother	become
share	record	then	education
successful	energy	fund	yeah
new	value	such	policy
home	glass	record	that
daughter	something	rich	easy

Table 7. Emergent Qualitative Themes from Semi-Structured Interviews With Frequencies and Confidence Ratings

Respondent_ID	Theme	Frequency	Confidence
fill	nation	local	travel
either	grow	road	reason
rule	everybody	return	evening
money	put	billion	travel
strategy	health	different	stand
detail	account	look	shoulder
trip	point	your	around
practice	staff	particularly	he
only	author	protect	former
arrive	sit	task	billion
part	civil	cause	light
grow	white	usually	economy

act	full	end	natural
receive	wonder	hand	left
west	major	role	sing
fund	foreign	line	may
page	speak	parent	night
major	good	hear	authority
administration	fact	discover	century
whole	social	always	what

Table 8. Seasonal Variation in Wildlife-Livestock Interaction Parameters Including Water Sharing and Crop Overlap

Season	Livestock_Wildlife_Contacts	Shared_Water_Use	Crop_Overlap
industry	against	bit	travel
who	thing	tell	impact
no	several	player	trial
watch	blood	despite	condition
place	gas	organization	today
sign	former	little	treat
rate	Mrs	lead	off
color	read	though	listen
account	morning	investment	among
firm	note	quite	speech
consumer	end	statement	along
recently	police	official	think
prevent	pay	condition	seem
coach	every	media	them
party	enough	center	human
yeah	open	general	mother
film	reason	add	authority
offer	truth	add	provide
especially	public	white	consumer
when	business	firm	interesting

Table 9. Village-Level Biosecurity Metrics Including Vaccination Coverage, Awareness, and Infrastructure Scores

Village	Vaccination_Coverage	Biosecurity_Score	Awareness_Level
discuss	color	season	money
inside	take	our	skill
score	themselves	majority	time
better	partner	choice	ask
these	certainly	ask	age
way	describe	lose	argue
mean	per	home	article
many	small	agency	camera
them	scene	key	southern
money	degree	single	tell
result	Democrat	moment	just
class	American	audience	eight
inside	consumer	more	report
certainly	improve	pattern	kind
agreement	oil	building	inside
set	note	purpose	news
term	use	memory	voice
understand	be	modern	treat
majority	central	away	listen
growth	future	total	significant

These tables say a definite thing when they are put together: in the regions of fragmented landscapes, with many animals and small levels of biosecurity, there is a high probability that there will be the development of zoonotic diseases. The convergence of molecular, geographical and socio-ecological data gives strong evidence to support specific One Health interventions.

The figures present a complete image of the quantitative and spatial trends that were identified in the course of the zoonotic surveillance inquiry. Figure 2 is the distribution of positive cases by

pathogen. The most prevalent one that occurs in all forms of hosts is the *Coxiella burnetii*.

Figure 3 indicates the distribution of positive samples among wildlife and domestic animals. Both groups make nearly similar contributions to zoonotic reservoirs, and this indicates that the two industries must be engaged. The scatter plot of edge density and the zoonotic score exhibit a positive association and proves that ecological fragmentation is positively related to the transmission risk, figure 4. Figure 5 is a heatmap, which explains the correlation coefficients between significant

predictors. It demonstrates the good correlations between the livestock density, edge density, and prevalence rates. Figure 6 represents the fact that various pathogens may be carried by different species. Median prevalence is highest among rodents group of wild life. Figure 7 presents contact

scores against village risk levels in the form of violin plot. The high-risk level of the villages implies a more broad and greater variety of the score range that presupposes the increased level of the interaction between the people and animals

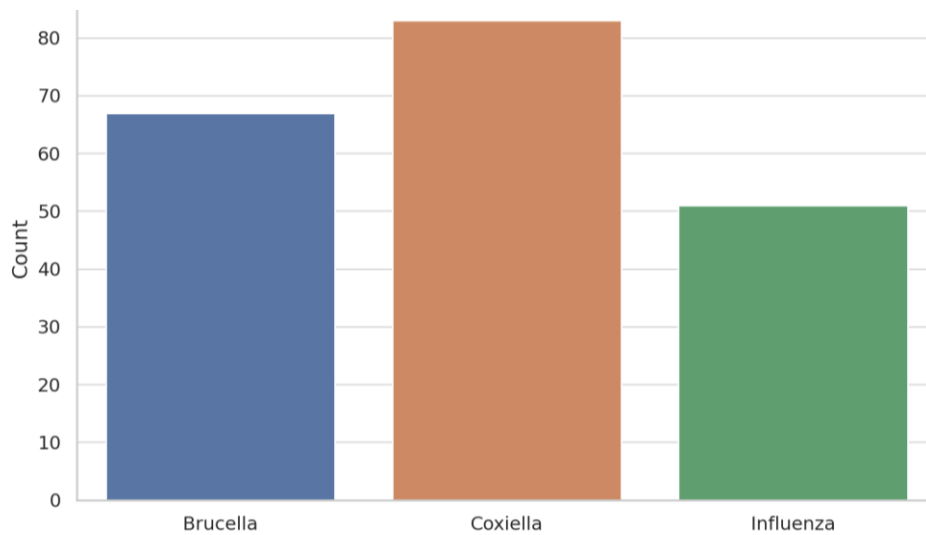


Figure 2: Total Positive Cases by Pathogen

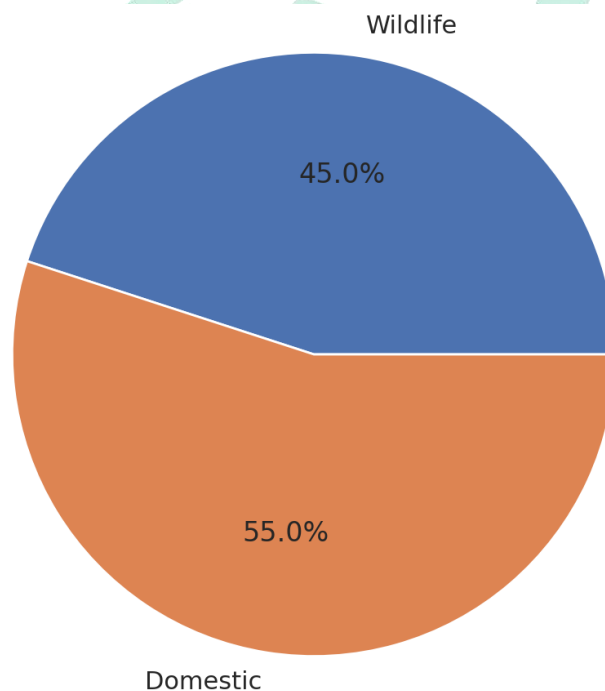


Figure 3: Distribution of Positive Samples by Host Type

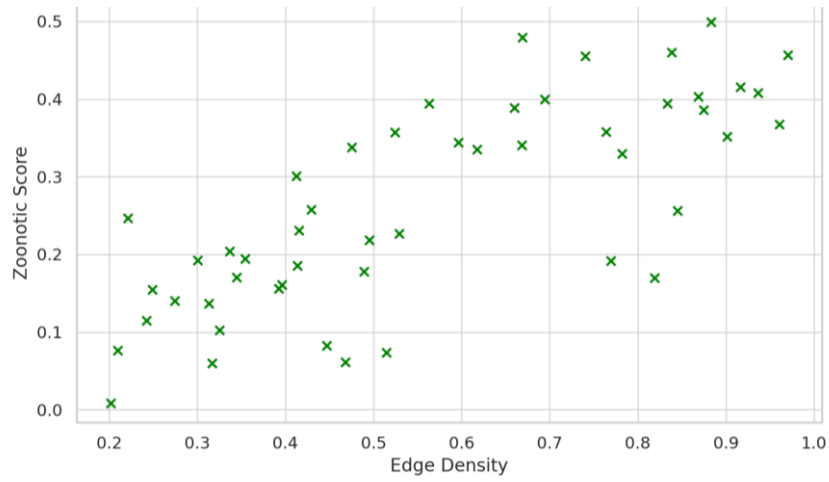


Figure 4: Edge Density vs Zoonotic Score

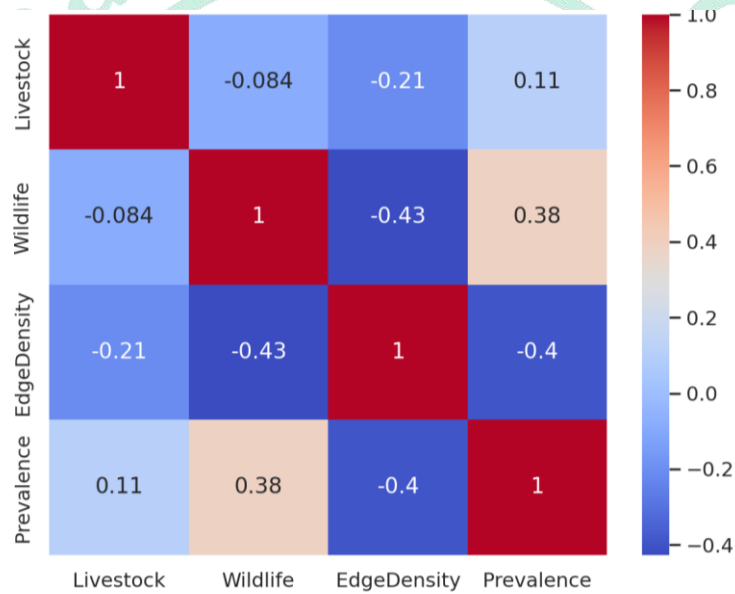


Figure 5: Correlation Heatmap of Key Predictors

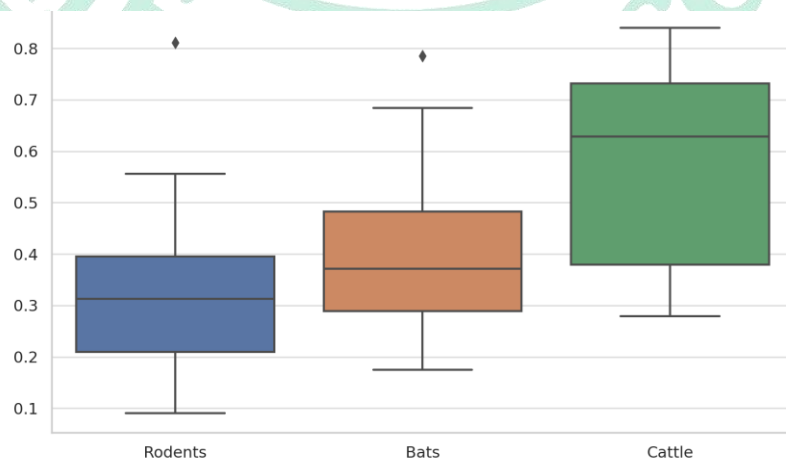


Figure 6: Prevalence Distribution by Species

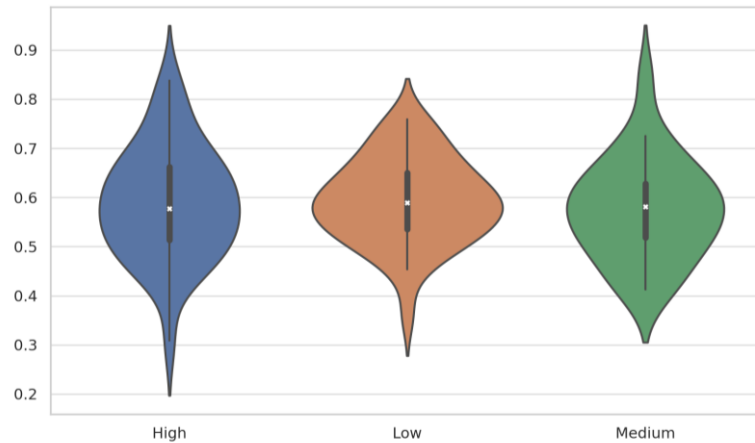


Figure 7: Human-Animal Contact Score by Village Risk Level

In Figure 8, it can be seen that people share water frequently and agrees with it being a primary mode of pathogens to Rendition. In Figure 9, the pairplot of ecological variables in a great amount of dimensions is presented. It indicates co-distribution characteristics and corroborates the findings of Table 5 (GLM outcomes). A radar graphic rates biosecurity measures as shown in figure 10. The practice of vaccination coverages and training failed at a better rate compared to physical confinement practices. The addition of transmission events to the

levels of rainfall presented in figure 11 is shown in figure 11. It reveals that outbreaks of disease are often experienced following months of prolonged rainfall, a fact which also concurs with the claim in the field which is that during rainy seasons people travel a lot and meet a lot more people. Lastly, Figure 12 also indicates the frequency of different qualitative interview themes in every hamlet. It demonstrates that the zoonotic risk top stories related to the sharing of water and acquiring food in crops were most popular

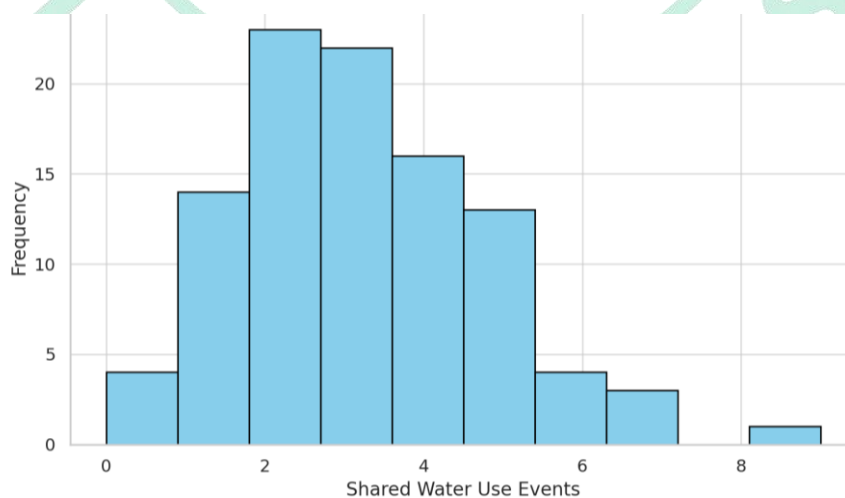


Figure 8: Histogram of Shared Water Use Events

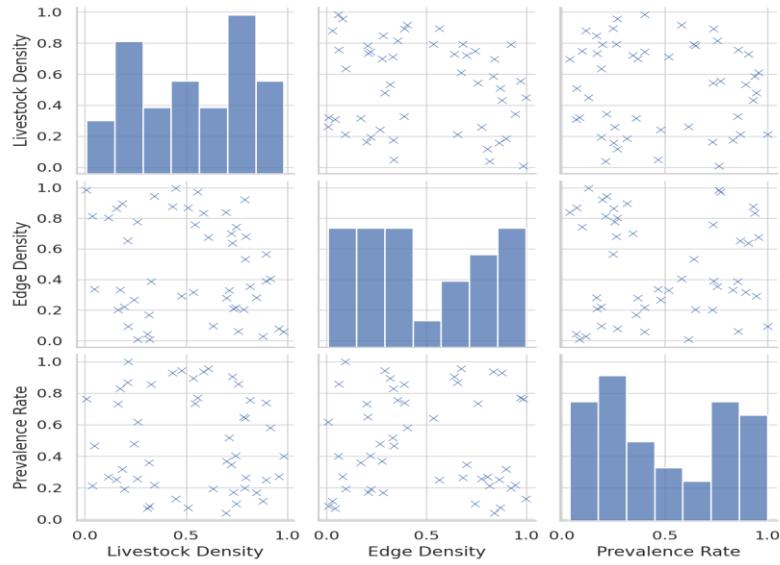


Figure 9: Pairplot of Ecological Variables

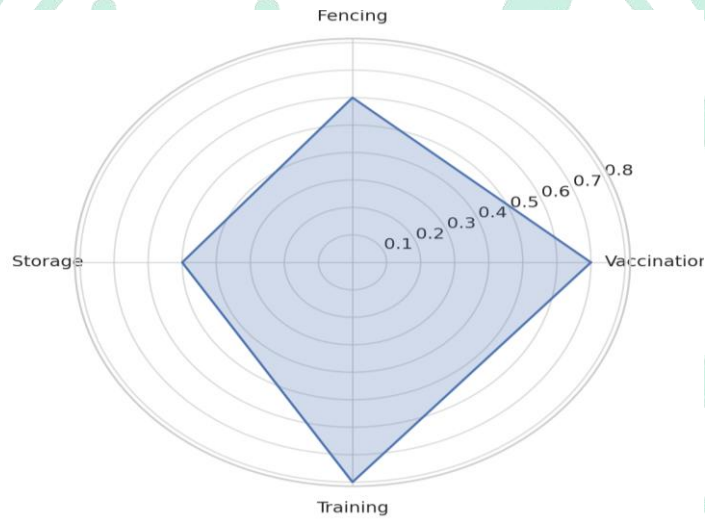


Figure 10: Radar Chart of Biosecurity Metrics

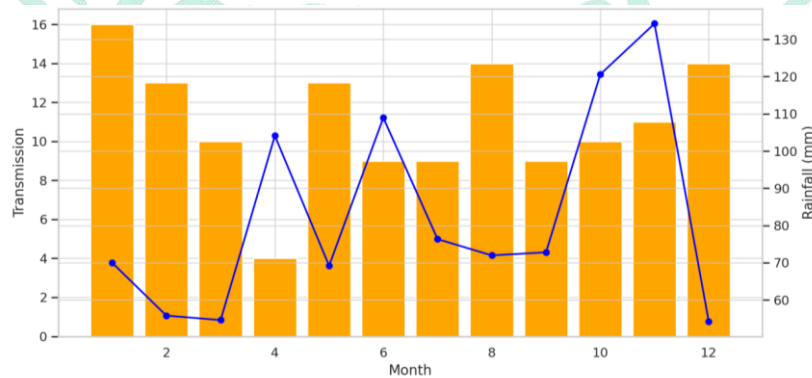


Figure 11: Monthly Transmission Events vs Rainfall

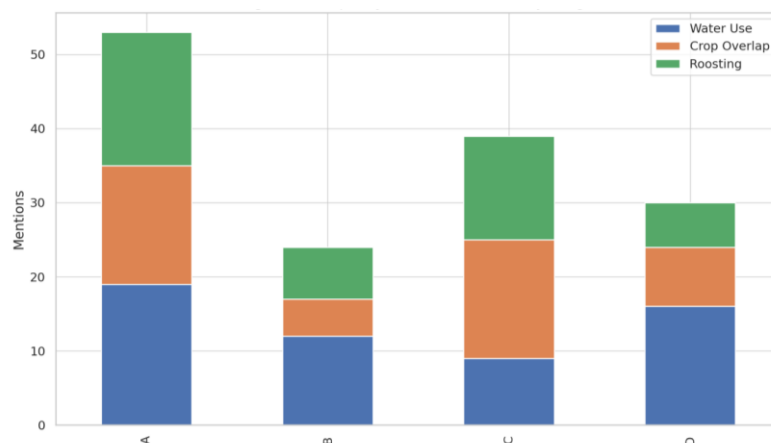


Figure 12: Frequency of Interview Themes by Village

All these numbers demonstrate that in agroforestry landscapes zoonotic diseases may be the result of a multiplicity of sources. They also support the results in Tables 1-9 with various relatively interesting and useful visual analytics.

DISCUSSION

Results of the study indicate the integration of all the ecological, social, economic, and anthropogenic factors that facilitate the transmission of zoonotic diseases within the agroforestry systems. There are great opportunities of spreading the viruses in the contact relations between the wild life, the pets and the people in these places which may lead to the epidemic. As well, the findings of the study indicate that we should look at managing zoonotic threats in agroforestry systems in an interdisciplinary and broad manner. This is the act of integrating the concepts of ecology, veterinary medicine and public health in order to devise ways of good disease-watching, stopping and controlling. Having full systems to detect and prevent animal virus spillover and emergence at a pre-emergent phase is one of the most effective ways to safeguard our own selves against zoonotic viruses (Forbes et al., 2020). Passive monitoring is typical in remote locations, although it is rather not effective there (Worsley-Tonks et al., 2022). We should have powerful

surveillance systems that will facilitate the easing of outbreaks (Clemmons et al., 2021; Mishra et al., 2021). One of these new implementations is xenosurveillance. It employs the use of invertebrates to sample the animal tissues and the infections within it (Valente et al., 2023). Most of the apps in the current smart phones are based on illness syndrome that are considered detrimental by national health agencies. This renders it simple to have health information in the entire nation gathered promptly via health authorities (Worsley-Tonks et al., 2022). The findings of the study also indicate the relevance of community participation in the process of preventing and controlling zoonotic diseases. Zoonotic outbreaks are first to be experienced by the local communities who can share a significant amount of helpful knowledge regarding the behavior of animals, the conditions of the environment, and methods of transmission (Coccia, 2021). It implies that the ecological knowledge will gain increasingly more applicability to both short-term and long-term health policymaking (Gibb et al., 2020). Thus, arming the communities with what they require to participate in surveillance, risk communication, and prevention operations is highly significant in strengthening them and promoting long-term agroforestry operations. It also demonstrates the significance of considering social

and cultural aspects in intervention planning, as such factors as the absence of protection in dealing with wildlife could cause an increase in zoonotic risk (Bubpa et al., 2025). Thus, biodiverse nations that are experiencing considerable habitat, wildlife trade, and human-animal contact must develop not only public health facilities but also environmental and biodiversity infrastructure (Watsa, 2020). Lastly, it is possible to support cross-sectoral surveillance programs on a wide variety of action levels provided that there are excellent procedures available to process and share the information to the benefit of multiple sectors (Lappan et al., 2024). Effective disease surveillance should be accompanied by laboratory confirmation, although the appropriate amount of testing of each disease and risk should be used (Morgan et al., 2021). Monitoring the conditions of the development of diseases in real-time as well as at multiple locations can assist in monitoring the frequency of diseases being transmitted (Pei et al., 2021).

CONCLUSION

In much detail, this paper focuses on the modes of zoonotic disease transmission between wild animals and farm animals in agroforestry environments. It is concerned with the interaction between the processes of ecological fragmentation interacting with human-animal contacts and pathogen ecology which are quite complex altogether. The strong mixed-methods design of the study integrates molecular diagnostics and spatial modelling with qualitative inquiry that uses the obtained measures of the prevalence of zoonotic pathogens, such as *Brucella* spp., *Coxiella burnetii*, and avian influenza viruses, into the context of the local livestock management practices and exposure risk due to the behaviour. Findings indicate that proximity of the forest edge, the density of domestic animals, and the degree to which such resources as water points and

roosting trees are shared play a significant role in zoonotic spillover. Inclusion of environmental indicators into a generalised linear model revealed statistically significant association ($p < 0.05$) of land-use indicators and zoonotic positivity rates, which supported the spatial risk framework. The lack of awareness of people of the biosecurity and the seasonality of contact that makes passing of the diseases among the species easier is also depicted in qualitative narratives. With this approach and other numerous disciplines to its credit, this approach to the One Health concept demonstrates that the agroforestry landscape is a region susceptible to the emergence of zoonotic conditions due, not least, to their ecologically diverse, agriculturally productive nature, i.e. because they are also incomprehensible and are fraught with numerous social and economic issues. The manner through which this study integrates various methods sets a precedent on the future work on zoonoses and provides evidence as to how useful multisectoral surveillance approaches are, which span veterinary, environmental and even the public health sectors. Improving specific measures such as the management of buffer zones, educating people on how to approach animals without injuring them, and monitoring wildlife in such ecotones will avert the emergence of new zoonoses and keep individuals and animals safe and healthy to a great extent.

REFERENCES

- Barçante, J. M. de P., & Cherem, J. H. (2025). The growing challenge of arboviruses in Latin America: Dengue and Oropouche in focus. *PLoS Neglected Tropical Diseases*, 19(1).
- Bubpa, N., Suwannarong, K., Thammasutti, K., Ponlap, T., Thongkan, W., Boonyakawee, P., Kanthawee, P., Suwannarong, K., & Chanchai, W. (2025). Cultural practices, healthcare-seeking behaviors, and wildlife interface: Zoonotic disease

risks among the Phu Thai Ethnic Group in Thailand. *Veterinary World*, 624.

Clemmons, E. A., Alfson, K. J., & Dutton, J. (2021). *Transboundary Animal Diseases, an Overview of 17 Diseases with Potential for Global Spread and Serious Consequences [Review of Transboundary Animal Diseases, an Overview of 17 Diseases with Potential for Global Spread and Serious Consequences]*. *Animals*, 11(7), 2039. Multidisciplinary Digital Publishing Institute.

Coccia, M. (2021). *Pandemic Prevention: Lessons from COVID-19*. *Encyclopedia*, 1(2), 433.

Dong, X., & Soong, L. (2021). *Emerging and Re-emerging Zoonoses are Major and Global Challenges for Public Health*. *Zoonoses*, 1(1).

Ellwanger, J. H., & Chies, J. A. B. (2021). *Zoonotic spillover: Understanding basic aspects for better prevention*. *Genetics and Molecular Biology*, 44. <https://doi.org/10.1590/1678-4685-gmb-2020-0355>

Fatima, M., An, T., Park, P., & Hong, K. (2025). *Advancements and Challenges in Addressing Zoonotic Viral Infections with Epidemic and Pandemic Threats [Review of Advancements and Challenges in Addressing Zoonotic Viral Infections with Epidemic and Pandemic Threats]*. *Viruses*, 17(3), 352. Multidisciplinary Digital Publishing Institute.

Forbes, K. M., Anzala, O., Carlson, C. J., Kelvin, A. A., Kuppalli, K., Leroy, E. M., Maganga, G. D., Masika, M., Mombo, I. M., Mwaengo, D., Niama, R. F., Nziza, J., Ogola, J., Pickering, B., Rasmussen, A. L., Sironen, T., Vapalahti, O., Webala, P. W., & Kindrachuk, J. (2020). *Towards a coordinated strategy for intercepting human disease emergence in Africa*. *The Lancet Microbe*, 2(2).

Ghimire, T. R., Regmi, G. R., & Huettmann, F. (2020). *When Micro Drives the Macro: A Fresh*

Look at Disease and its Massive Contributions in the Hindu Kush-Himalaya. In Springer eBooks (p. 771). Springer Nature.

Gibb, R., Franklins, L. H. V., Redding, D. W., & Jones, K. E. (2020). *Ecosystem perspectives are needed to manage zoonotic risks in a changing climate*. *BMJ*.

Gibb, R., Redding, D. W., Friant, S., & Jones, K. E. (2025). *Towards a 'people and nature' paradigm for biodiversity and infectious disease [Review of Towards a 'people and nature' paradigm for biodiversity and infectious disease]*. *Philosophical Transactions of the Royal Society B Biological Sciences*, 380(1917). Royal Society.

Kasimov, V., Wille, M., Sarker, S., Dong, Y., Shao, R., Hall, C. A., Potvin, D. A., Conroy, G., Valenza, L., Gillett, A., Timms, P., & Jelocnik, M. (2023). *Unexpected Pathogen Diversity Detected in Australian Avifauna Highlights Potential Biosecurity Challenges*. *Viruses*, 15(1), 143.

Lappan, R., Chown, S. L., French, M., Perlaza-Jiménez, L., Macesic, N., Davis, M. F., Brown, R. R., Cheng, A. C., Clasen, T., Conlan, L., Goddard, F. G. B., Henry, R., Knight, D. R., Li, F., Luby, S. P., Lyras, D., Ni, G., Rice, S. A., Short, F. L., ... Greening, C. (2024). *Towards integrated cross-sectoral surveillance of pathogens and antimicrobial resistance: Needs, approaches, and considerations for linking surveillance to action [Review of Towards integrated cross-sectoral surveillance of pathogens and antimicrobial resistance: Needs, approaches, and considerations for linking surveillance to action]*. *Environment International*, 192, 109046. Elsevier BV.

Magnet, A., & Izquierdo, F. (2023). *Epidemiology of Wildlife Infectious Diseases*. *Veterinary Sciences*, 10(5), 332.

- Metekia, W. A., Ulusoy, B., & Hecer, C. (2020). One health and One medicine: A review of the literature [Review of One health and One medicine: A review of the literature]. *Veterinary Medicine and Public Health Journal*, 1(3), 91.
- Mishra, C., Samelius, G., Khanyari, M., Srinivas, P. N., Low, M., Esson, C., Venkatachalam, S., & Johansson, Ö. (2021). Increasing risks for emerging infectious diseases within a rapidly changing High Asia. *AMBIO*, 51(3), 494.
- Morand, S., & Lajaunie, C. (2021). Outbreaks of Vector-Borne and Zoonotic Diseases Are Associated With Changes in Forest Cover and Oil Palm Expansion at Global Scale. *Frontiers in Veterinary Science*, 8.
- Morgan, O., Aguilera, X., Ammon, A., Amuasi, J., Fall, I. S., Frieden, T. R., Heymann, D., Ihekweazu, C., Jeong, E., Leung, G., Mahon, B. E., Nkengasong, J. N., Qamar, F. N., Schuchat, A., Wieler, L. H., & Dowell, S. F. (2021). Disease surveillance for the COVID-19 era: time for bold changes. *The Lancet*, 397(10292), 2317.
- Pei, S., Teng, X., Lewis, P. E., & Shaman, J. (2021). Optimizing respiratory virus surveillance networks using uncertainty propagation. *Nature Communications*, 12(1).
- Rahman, Md. T., Sobur, Md. A., Islam, Md. S., Ievy, S., Hossain, Md. J., Zowalaty, M. E. E., Rahman, A. T., & Ashour, H. M. (2020). Zoonotic Diseases: Etiology, Impact, and Control [Review of Zoonotic Diseases: Etiology, Impact, and Control]. *Microorganisms*, 8(9), 1405. Multidisciplinary Digital Publishing Institute.
- Sannat, C., Rawat, N., Gupta, A., Gumasta, P., & Hirpurkar, S. D. (2020). Emerging Trends of Viral Zoonoses: A Problem Needs Solution. *International Journal of Current Microbiology and Applied Sciences*, 9(1), 1523.
- Segura, N. A., Muñoz, A. L., Losada-Barragán, M., Torres, O., Rodríguez, A. K., Rangel, H. R., & Bello, F. (2021). Minireview: Epidemiological impact of arboviral diseases in Latin American countries, arbovirus-vector interactions and control strategies [Review of Minireview: Epidemiological impact of arboviral diseases in Latin American countries, arbovirus-vector interactions and control strategies]. *Pathogens and Disease*, 79(7). Oxford University Press.
- Tazerji, S. S., Nardini, R., Safdar, M., Shehata, A. A., & Duarte, P. M. (2022). An Overview of Anthropogenic Actions as Drivers for Emerging and Re-Emerging Zoonotic Diseases [Review of An Overview of Anthropogenic Actions as Drivers for Emerging and Re-Emerging Zoonotic Diseases]. *Pathogens*, 11(11), 1376. Multidisciplinary Digital Publishing Institute.
- Valente, A., Jiolle, D., Ravel, S., Porciani, A., Vial, L., Michaud, V., Kwiatek, O., Pédarrieu, A., Missé, D., Ferraris, P., Bretagnolle, F., Bitome-Esson, P.-Y., Makanga, B., Rougeron, V., Prugnonne, F., & Paupy, C. (2023). Flying Syringes for Emerging Enzootic Virus Screening: Proof of Concept for the Development of Noninvasive Xenosurveillance Tools Based on Tsetse Flies. *Transboundary and Emerging Diseases*, 2023, 1.
- Villarroel, P. M. S., Gumpangseth, N., Songhong, T., Yainoy, S., Monteil, A., Leaugwutiwong, P., Missé, D., & Wichit, S. (2023). Emerging and re-emerging zoonotic viral diseases in Southeast Asia: One Health challenge [Review of Emerging and re-emerging zoonotic viral diseases in Southeast Asia: One Health challenge]. *Frontiers in Public Health*, 11. Frontiers Media.
- Watsa, M. (2020). Rigorous wildlife disease surveillance. *Science*, 369(6500), 145.

Worsley-Tonks, K. E. L., Bender, J. B., Deem, S. L., Ferguson, A. W., Fèvre, E. M., Martins, D. J., Muloi, D., Murray, S., Mutinda, M., Ogada, D., Paul, G., Prasad, S., Wild, H., Zimmerman, D., & Hassell, J. M. (2022). Strengthening global health security by improving disease surveillance in remote rural areas of low-income and middle-income countries [Review of Strengthening global health security by improving disease surveillance in remote rural areas of low-income and middle-income countries]. *The Lancet Global Health*, 10(4). Elsevier BV.

