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Northeast India and Its Vulnerability to Zoonotic Diseases: A Review

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ABSTRACT

Epidemiological studies in recent years have pointed towards an environmental component in the outbreak of any disease or epidemic in various parts of the world. Owing to increasing urbanization that has come at the enormous cost of deforestation and changes in land use, we have come into closer interactions with the unknown world of microbes and bacteria that were previously contained in the wild. Northeast India is a species-rich region that falls within the Indo-Burma Biodiversity Hotspot, containing numerous indigenous tribes within it with varying cultures among them. The consumption pattern of species or the food habits, climate and frequent flooding has increased in the last few years at an alarming rate, heightening the risk of zoonotic diseases, examples of which include COVID-19, Ebola, and various strains of influenza. The present paper focuses on the probable outbreak of new pathogens in northeast India, and it also discusses the history of some pathogenic transmission in the region with factors favourable for new outbreaks.

Keywords: Zoonotic diseases, Pathogens, Indo-Burma hotspot, deforestation.

INTRODUCTION:

Areal diffusion of bacteria and viruses has a long history. The '*measles virus*' is said to have evolved from '*rinderpest virus*' (found in cattle); agents of the common cold are from 'rhinoviruses', which came to us from horses; and 'smallpox' is a derivative of the cowpox. The extent is baffling when we consider the case of the Middle East respiratory syndrome coronavirus (MERS-CoV), a virus first found in the Arabian Peninsula in 2014, which biologist believe was probably first passed to people by camels, but it may have originated in bats -thus even a hostile desertic environment could not restrict the spread of the virus **(Mackay & Arden,**

2015). The findings of the team of Guangzhou, China, are alarming because the particular species they spoke about, i.e., the Malayan Pangolins (Manis Javanica), shares a vast geographical territory that includes our very own North East India.

Among the above-mentioned viruses, the very new as well as very deadly virus that drew the attention of the entire world in a few weeks after its emergence is the Novel Coronavirus, which was further renamed as 'Covid-19'. This virus shook the entire world in recent times by its mutation effect, and it first emerged in December 2019 when the first case was recorded in Wuhan, China (1151 km away from Beijing). In the initial stage, it was thought to be a type of 'Pneumonia' but later it was called 'severe acute respiratory syndrome- Coronavirus 2' shortly 'SARS-CoV-2' **(Spiteri et.al., 2020)**. According to a specific research agency, a total of 529,821,934 cases have been reported so far as of May 2022 from January 2020, of which 62,92,128 persons died up to the same date **(Global Data, 2022)**. The spectrum of the pandemic was so immense that it had brought the world economy to a standstill, not to mention the fundamental changes it brought to our lives.

COVID-19 was one of the major incidences of zoonoses that caught global attention. However, almost every year, several parts of the world are ravaged by epidemics and diseases of zoonotic origin. Some manage to get traction in the media, while many go unreported. In this study, an attempt has been made to bring to focus the looming dangers of epidemics of zoonotic origin in North East India, which remains largely isolated from mainstream India's media lenses. Many epidemics and diseases of zoonotic origin have emerged in recent years in the Northeast, which have not received adequate attention. The dangers of Mutation and Altered Tropism/Replication lurk behind the darkness, in the interactions between pathogens and viruses, which can spill over to humans, causing irreparable losses to tribal communities and fragile ecosystems of North East India.

Zoonotic diseases are mainly transmitted to the human body through various animals and getting involved with these pathogen-carrying animals can pose serious health threats. Areas with high rainfall often cause flooding, where these pathogens are contaminated with water and further enter the human body **(Markson, 2022).** Besides, the food habits of northeast Indian people are quite unique from the rest of the country, where numerous types of animals and insects are consumed, which is part of their tradition too **(Kadirvel et al., 2021; Pradhan, Sahoo, Hazarika et al., 2022)**. Northeast India falls within the monsoon belt, where majority of the time, due to intense rainfall, flooding takes place. Northeast India, as a part of the Indo-Burma Biodiversity Hotspot, has a unique geography with a species-rich region **(Hazarika,**

2021) that has a very high tendency to transmit deadly pathogens, which have a previous record of transmission. Very limited studies on this issue have taken place in this region and the potential pathogenic transmission should be identified to reduce the risk in the near future. This study will explore the various facets of zoonoses, from their origin to geographical and cultural factors aiding their dissemination in the Global and North-east Indian context, also outlining some of the factors that have contributed to the origin and spread of epidemics and diseases of zoonotic origins in Northeast India.

METHODOLOGY:

The database used for this paper mainly relies on secondary sources. It mainly relies on the reports of reputed global institutions, research papers of various fields, books, newspaper cuttings, etc. The collected database has then been analyzed through existing published literature. Mainly, this paper tries to incorporate the field of biological science with geography and the environment. Hence, some specific pathogens, their host, i.e., animals through which they transmit, and the regions where favorable conditions exist for their transmission, along with the record of records of historical transmission, are studied. Along with it, it is made to show the global epidemics, endemic and pandemic situations that occurred at different times and their causes, especially those that have evidence of anthropogenic interference. The study mainly focuses on one of the world's most fragile biodiversity hotspots- the Indo-Burma biodiversity hotspot.

Northeastern India and The Indo-Burma Biodiversity

The study will concentrate on the northeastern region of India where a very diverse ecology exists. Numerous tribes reside in the hill states of the region and all of them are distinct from one another in terms of economy, culture and society, and all of these have been shaped by their natural setup. This region falls in one of the most fragile ecological regions located in Southeast Asia- The Indo-Burma biodiversity hotspot which covers a geographical area of 2,400,000 sq.km. **(IUCN & UNEP, 2014)** of tropical Asia, east of the Ganges-Brahmaputra lowlands. The area contains the Lower Mekong catchment. It begins in eastern Bangladesh and then extends across north-eastern India (except Arunachal Pradesh), south of the Brahmaputra River, to encompass nearly all of Myanmar, part of southern and western Yunnan Province in China, all of the Lao People's Democratic Republic, Cambodia and Vietnam, the vast majority of Thailand and a small part of Peninsular Malaysia. In addition, the hotspot covers the coastal lowlands of southern China, as well as several offshore islands in the South China Sea and the Andaman Islands (of India) in the Andaman Sea **(Sclater, 1858; Wallace, 1876; Cox, 2001)**.

Fig 1: Indo-Burma Biodiversity Hotspot

(Conservation International, 2012)

The Indo-Burma Hotspot is one of the most environmentally threatened hotspots in the world, as it was one of the first places where humans developed agriculture, and has a history of using fire to clear land for agriculture and other needs. As the hotspot is one of the most species-rich and home to many endangered species found nowhere else, the current threat is even more alarming. The Pangolins that are under scanner and are thought to be the carrier of Covid 19 have a total of 8 species all over the world, of which 4 pangolin species are found in Asia: Chinese pangolin (Manis pentadactyla), Sunda pangolin (Manis javanica), Palawan pangolin (Manis culionensis), Indian pangolin (Manis crassicaudata). The Sunda pangolin which has been specially identified as carrier, is found southeastern Asia within the Indo-Malayan regions covered by the Indo Burma Hotspot. Pangolins are listed under threatened in IUCN red list and have the highest protection under CITES **(IUCN, 2017)**. The international trade of Pangolins has been banned. But illegal trafficking is widespread. In several parts of East Asia, they are illegally sold, for their meat and scales, and for use in traditional Chinese medicine, in which parts of the animal are used to treat ailments such as skin diseases, menstrual disorders and arthritis **(Conciatore, 2019)**. Chinese law states that people selling pangolins can be punished by 10 years or more in prison, and even Pangolins were not listed on an inventory of items sold at the Wuhan market, from where the virus is supposed to have spread — although the illegality of trading pangolins could explain this omission.

ANALYSIS & DISCUSSION

The Spectre of Zoonoses

Biologist have termed a zoonosis (zoonotic disease or zoonoses -plural) as an infectious disease that is transmitted naturally between species from animals to humans (or from humans to animals) **(Vourc'h, et al., 2022)**. Of the more than 1,700 known viruses, bacteria, and other pathogens that infect people, more than half either originated in or now come directly from animals. The rest come from the environment around us, such as soil, water, and air. And of the 37 new infectious diseases identified in the past 30 years, more than two-thirds originated in animals. By a conservative analysis however, the total number of zoonoses is unknown, but according to Taylor, out of 1,415 known human pathogens, 62% were of zoonotic origin **(Taylor, et.al., 2001)** while according to Woolhouse, Jones and Fong, about 60-75% of the existing viruses in the world are zoonoses **(Woolhouse & Gotwage, 2005; Jones, et.al., 2008; Fong, 2017)**. With time, more and more human pathogens are found to be of animal origin. Moreover, most emerging infectious diseases in humans are zoonoses. Wild animals seem to be involved in the study dealing with the transmission and control of disease (epidemiology) of most zoonoses and serve as major reservoirs for the transmission of zoonotic agents to domestic animals and humans.

Zoonoses are caused by germs (like viruses or bacteria) that can make one type of animal sick. What makes these germs special is their ability to infect more than one kind of animal, including humans. This ability to move from one species to another is called "crossing or jumping the species gap." In simple terms, these germs can jump from animals to humans, causing disease in both.

Although healthcare is undergoing rapid developments with new medications and techniques, there is also a continual challenge from newly identified pathogens and diseases. These are often identified and differentially diagnosed only by the improvement in or development of investigative techniques. About 80% of these new diseases and pathogens are zoonotic. The emergence of a new zoonosis may not be linked just to the ability of the causative agent to cross the species barrier, although this is a significant factor. The pathogen must have the opportunity to cross that barrier, always including interspecies contact, which is often related to a variety of other external factors **(Shakespeare, 2009)**.

Shakespeare (2009) also observes that a change in the ecosystem, the meteorological pattern, global warming, farming practice or food handling can significantly alter the potential that a known or unknown pathogen has to cause disease in humans (with humans coming into closer or more prolonged contact with carrier species). After this contact, there needs to be pathogen transmission, either directly or via a vector, such as a biting insect, and this transmission must

be sustainable, with the pathogen in some cases colonizing the vector if there is one. Once these conditions have been met, the pathogen may also adapt to human physiology and immunology. A factor that often characterizes an emergent pathogen is its ability to undergo gradual genetic modification, in a manner reminiscent of Darwin's finches, so that it reinvents itself as better adapted to exist in a particular population. This change can enable an organism, which is benign in other species, to become an efficient pathogen in humans or animals **(Shakespeare, 2009).** Another factor is exposure: in many parts of the world, deforestation or the pressure on other habitats brings humans and animals into close proximity. Sometimes these will be species or populations that have previously remained apart. As we know from the introduction of smallpox into the Americas by the Spanish, the result of the exposure of previously unexposed groups to a novel pathogen can produce devastating effects **(Shakespeare, 2009)**.

The careful study of the associated epidemiology of emerging diseases, and their routes of infection and natural reservoirs, is the only way to gain the insights necessary to put in place the measures needed to prevent epidemic zoonosis outbreaks. This is true for several of the zoonoses mentioned in this chapter; scientists and health professionals involved in the control of the outbreaks had to make informed assumptions from the case profiles or epidemiological pattern. It is only on subsequent investigation that their assumptions can be proved. Wherever the assumptions or deductions made are of importance, they are included in the text as examples of the processes essential to disease management. A factor that needs to be considered about all the diseases explored in this section is that emerging infections or diseases may be re-emerging. Systems break down, and the reasons for public or personal health measures may become forgotten or lost in the mists of time. Several pathogens that were scourges of past ages are showing a resurgence, with outbreaks highlighting ageing or decaying infrastructure systems, such as sewage or water treatment, and the failure of consumers to know, understand, or heed common-sense warnings related to animal handling or food preparation. It is also worth noting that the knowledge base of most healthcare practitioners does not extend beyond their years; we are all children of our times. Symptoms and signs that would historically have sent alarm messages are ignored or pass unseen. The lesson from the current outbreaks of human tuberculosis in the UK is that pathogens can only rarely be designated as eradicated; they are more likely to be in a state of abeyance, awaiting the chance to go on a rampage of infection.

The price of our continued safety in Western Europe and the USA, behind the ramparts of our healthcare and social systems, is constant vigilance. Worldwide, this role is borne by public organizations charged with the monitoring of public, human and animal health. In addition, the

WHO and other organizations, such as the Pasteur Institute, which have networks of laboratories worldwide that undertake surveillance on a spectrum of diseases, including some of zoonotic origin.

Detection and identification are assisted by continual testing of indicator populations for susceptible species. In the USA, the presence of WNV is monitored by just such a program, using regularly inspected captive domesticated birds to determine ambient levels of the causative organism. Similar to the canary in a cage in a submarine or mine, these precautions are designed to alert the experts and the populations for which they are responsible to the likelihood of an outbreak.

In the event of an outbreak of a zoonotic disease, there is a requirement for the lead organization to be identified quickly and for it to take charge of all aspects of the outbreak. On occasions, this is a difficult process because rivalry and maintenance of jurisdiction often become more of an issue than the disease itself. It behooves anybody involved with an outbreak to remember that all other issues are peripheral to controlling diseases and preventing human casualties and fatalities.

SPECIES CONSIDERED TO BE CARRIERS OF VIRUSES

Zoonosis pathogens are mainly transmitted to the human body through various animals and insects that exist in proximity to human civilization. Some of the species that are highly responsible and have history of spreading deadly diseases to human society are discussed below.

Rats are one of the most widespread species and are found globally. These rodents are highly resilient and can thrive in a variety of environments, from urban cities to rural landscapes. In North East India, rats are prevalent in agricultural fields, homes, and sewers, particularly in states like Assam and Meghalaya. The presence of rats in these areas can pose significant health risks to humans, as they are known to transmit diseases **(Battersby et al., 2002)** such as leptospirosis, plague and hantavirus. Leptospirosis is a bacterial infection that can be spread through contact with water or soil contaminated with the urine of infected rats. Annually, about 1.03 million cases of leptospirosis and 58,900 deaths are recorded globally. Mainly population belonging to 20-49 age group is being targeted by this disease **(Costa, Hagan et al., 2016)**. Similarly, Plague also considered as a quick spreading disease, especially in Asia and southeast Asia. In the Indo-Myanmar region, this disease has been reported to be upto 500 between 2000-2018.

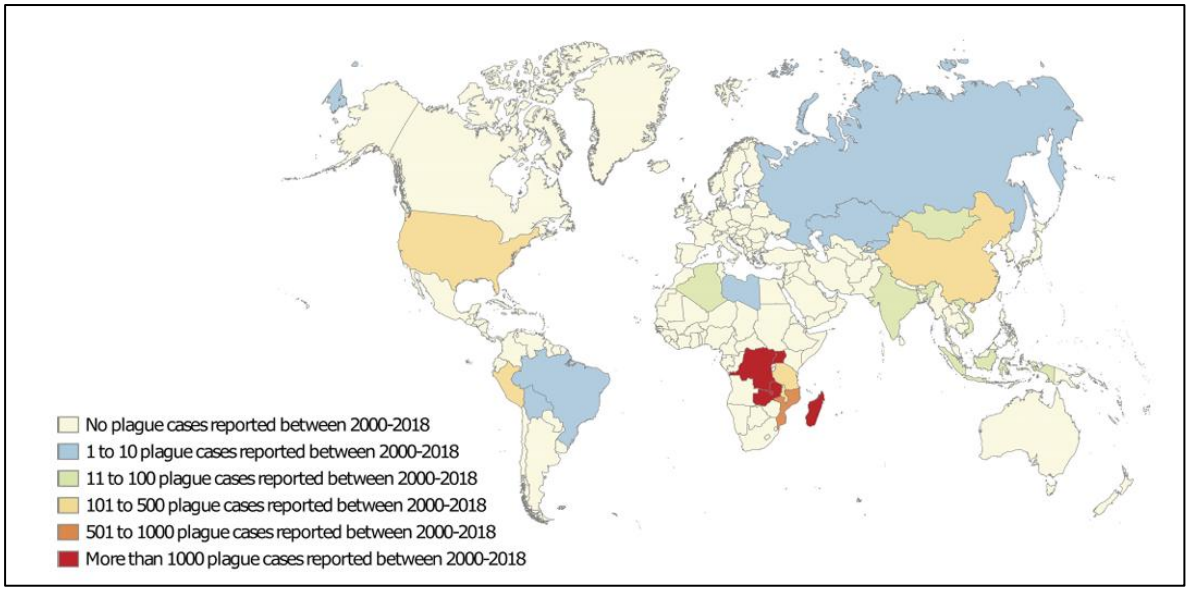

Fig 2: Registered Plague cases between 2000-2018 **(Barbieri, Signoli, Chevé, et al., 2021)**

Hantavirus, on the other hand, is a viral infection that can be spread through contact with rodents or their droppings. This disease can cause symptoms such as fever, fatigue, and muscle aches, and can be severe in some cases. Effective rodent control measures, such as proper waste management and sealing of entry points, can help reduce the risk of rat-borne diseases and economic losses.

Bats are considered to be a serious transmitter of zoonotic pathogens/diseases, and in India this species is common everywhere. Bats are vital pollinators and seed dispersers in its ecosystem and also a good pest controller, playing a crucial role in maintaining the health and diversity of tropical forests **(Biswas et al., 2020)**. These bats are known for their intelligence and have been observed using complex strategies to forage for food, including memory and spatial awareness. They are also skilled fliers, capable of covering long distances in search of fruit, nectar, and pollen and they have low fecundity rates, making them different from other sylvatic disease reservoirs **(Hayman et al, 2013)**. Many pathogens survive in bats and are transmitted to other animals when favourable ecological conditions are achieved. Pathogens like Nipah virus (NiV), Hendra virus (HeV), Ebola virus (EBOV), Marburg virus (MARV), severe acute respiratory syndrome coronavirus (SARS-CoV), Middle East respiratory syndrome (MERS) virus, etc., which have high transmissibility, have a high chance of being transmitted to others through bats.

Cats are domesticated animals found globally, with an estimated 600 million cats kept as pets, strays, homeless, feral, etc. **(Brien and Johnson, 2007)**. In North East India, cats are commonly kept as pets in urban and rural areas, providing companionship and affection to their owners.

However, cats can also pose health risks to humans, particularly through the transmission of diseases such as toxoplasmosis and cat scratch disease. Toxoplasmosis is a parasitic infection caused by Toxoplasma gondii, which can be transmitted through contact with contaminated cat feces or undercooked meat. Cat scratch disease, on the other hand, is a bacterial infection caused by Bartonella henselae, which can be transmitted through scratches or bites from infected cats **(Dubey, 2021)**. Proper cat care and hygiene practices, such as regular cleaning of litter boxes and washing hands after handling cats, can help reduce the risk of cat-borne diseases. Additionally, keeping cats indoors and providing regular veterinary care can also help minimize the risk of disease transmission.

Birds are found in diverse habitats worldwide, with over 10,000 species identified **(Jetz, Thomas et al., 2012)**. In North East India, birds like the Indian peafowl and the lesser adjutant stork are common, and their habitats range from forests to wetlands. However, birds can also pose health risks to humans, particularly through the transmission of diseases such as avian influenza and histoplasmosis. Avian influenza, commonly known as bird flu, is a viral infection that can be transmitted through contact with infected birds or contaminated surfaces. Histoplasmosis, on the other hand, is a fungal infection caused by inhaling spores from bird droppings. Bird owners and handlers are at risk of contracting these diseases, and proper precautions such as wearing protective gear and maintaining good hygiene can help reduce the risk of transmission. Understanding bird behavior and ecology can also help reduce the risk of bird-borne diseases. For instance, knowing how birds interact with their environment and other animals can inform strategies for preventing disease transmission. In North East India, where birds are an integral part of the ecosystem, it's essential to be aware of the potential health risks associated with birds and take steps to mitigate them. By taking precautions and being mindful of bird health, humans can coexist with birds while minimizing the risk of disease transmission. Birds play a vital role in maintaining ecological balance, and preserving their habitats is crucial for both human and animal health. Effective management of bird populations and their habitats can help prevent the spread of diseases, ensuring a healthier environment for both humans and birds.

Pigs are domesticated animals raised globally for meat, with over 115.6 million pigs raised annually **(Vida & Szűcs, 2020)**, and are found in various parts of the world, including Asia, Europe, and the Americas, with China, the United States, and Brazil being among the top pig-producing and consuming countries. In North East India, pig farming is a very popular practice found almost everywhere in the region, where pigs are raised for both local consumption and commercial purposes. However, pigs can also pose health risks to humans, particularly through

the transmission of diseases such as *swine influenza* and *Nipah virus* **(McLean & Graham, 2019)**. Swine influenza is a viral infection that can be transmitted through contact with infected pigs or contaminated surfaces, while Nipah virus is a zoonotic disease that can be transmitted through contact with infected pigs or other animals, such as bats. In North East India, the close proximity between humans and pigs, particularly in rural areas, increases the risk of disease transmission. Understanding pig behavior, ecology, and husbandry practices is crucial for reducing the risk of pig-borne diseases. Proper pig farming practices, such as maintaining good hygiene, providing regular veterinary care, and implementing biosecurity measures, can help minimize the risk of disease transmission. By adopting these practices, pig farmers in North East India can reduce the risk of disease transmission and promote a healthier environment for both humans and animals.

Snails are found in diverse habitats worldwide and are commonly found in tropical, subtropical, and temperate regions. In North East India, snails are commonly found in gardens, agricultural fields, and forests, particularly in areas with high humidity and rainfall, such as Assam, Meghalaya, and Arunachal Pradesh. Snails play a significant role in ecosystems as decomposers and are an important food source for many animals. However, snails can also transmit diseases to humans, particularly through the transmission of *schistosomiasis*, a parasitic disease caused by Schistosoma species. Snails serve as intermediate hosts for these parasites, which can infect humans through contact with contaminated water or soil **(Lu, Gu et al., 2018)**. In North East India, where snails are abundant in many areas, the risk of schistosomiasis transmission is higher, particularly in rural communities where access to clean water and sanitation may be limited and also snails are used as a food product **(Grimes, Croll, Harrison et al., 2015)**. Understanding snail behavior, ecology, and habitats is crucial for reducing the risk of snail-borne diseases. Effective snail control measures, such as eliminating standing water and using molluscicides, can help minimize the risk of disease transmission. By adopting these measures and promoting awareness about snail-borne diseases, communities in North East India can reduce the risk of schistosomiasis and promote a healthier environment for both humans and animals. Snail control is an essential aspect of public health initiatives in the region, and efforts to manage snail populations can have a significant impact on disease prevention and control.

Besides, there are several more animals that are very much responsible for the diffusion process and zoonotic pathogens.

ZOONOTIC DISEASES PREVALENT IN TROPICAL AND SUBTROPICAL REGIONS OF THE INDIA

Tropical and subtropical parts of India — especially the Northeast and southern states — often struggle with a high number of zoonotic diseases. This is largely due to a mix of environmental factors like heavy monsoons, thick forests and human activities such as deforestation, farming practices, food habits, etc. **(Morand & Lajaunie, 2021)**. Common diseases in these regions include leptospirosis, scrub typhus, rabies, and Japanese encephalitis. On top of that, newer threats like Nipah virus and Kyasanur Forest Disease (KFD) are starting to appear, mostly as a result of changing ecosystems.

Japanese Encephalitis (JE): Japanese Encephalitis is caused by the Japanese encephalitis virus (JEV), which belongs to the flavivirus family — the same group that includes dengue and Zika. The virus is transmitted through the bite of infected *Culex* mosquitoes, particularly *Culex tritaeniorhynchus*. These mosquitoes often breed in rice fields and stagnant water. Pigs and certain water birds like herons and egrets act as the main reservoirs of the virus **(Mulvey et al., 2021)**. While they can carry and spread the virus, humans are considered "dead-end hosts"- meaning we can get infected, but we don't pass the virus on. People infected with JE may experience symptoms like high fever, headache, seizures, and even slip into a coma. Severe cases can be deadly, with a mortality rate of 20–30%. Many survivors suffer long-term neurological problems. Japanese Encephalitis is a serious public health concern in several parts of India. It is especially prevalent in the Northeast (like Assam and Arunachal Pradesh), Uttar Pradesh, and southern states such as Tamil Nadu and Karnataka. The mosquito that spreads JE thrives in warm, wet environments — especially in flooded rice paddies and wetlands, which are common in many tropical and subtropical parts of India **(Thangamathi, Nithya, Lavanya et al., 2018)**. The monsoon season creates ideal breeding conditions, and rural pig farming further adds to the risk by increasing the number of animal reservoirs in close contact with human populations. The cases of Japanese Encephalitis are quite considerable in India, with a large affected population belonging to the northeastern states. Assam alone has seen a large number of confirmed cases in recent years, and it has been highly affecting people in the monsoonal months **(National Health Profile, 2020)**.

Sl. No.	All States/UTs	2015		2016		2017		2018		2019 (P)	
		C	D	C	D	C	D	C	D	C	D
1	Andhra Pradesh	0	0	0	0	1	0	0	0	0	0
2	Arunachal Pradesh	32	2	0	0	5	0	0	0	68	2
3	Assam	614	135	427	92	604	87	509	94	642	161
4	Bihar	66	12	100	25	74	11	74	11	135	27
5	Chhattisgarh	0	0	0	0	0	0	0	0	53	5
6	Delhi	0	0	0	0	0	0	0	0	0	0
7	Goa	0	0	1	0	0	0	3	0	1	0
8	Gujarat	0	0	0	0	0	0	0	0	0	0

9	Haryana	2	0	2	0	4	1	0	0	0	0
10	Himachal Pradesh	0	0	0	0	0	0	0	0	0	0
11	Jammu & Kashmir	0	0	0	0	0	0	0	0	0	0
12	Jharkhand	116	8	47	5	29	1	66	0	112	3
13	Karnataka	27	1	11	0	26	2	35	5	33	4
14	Kerala	2	1	2	0	1	0	5	2	11	2
15	Madhya Pradesh	0	0	0	0	0	0	0	0	42	1
16	Maharashtra	7	0	12	1	27	0	6	1	35	10
17	Manipur	6	0	47	1	186	10	57	3	343	6
18	Meghalaya	41	8	47	4	48	4	90	6	191	9
19	Mizoram	0	0	0	0	0	0	0	0	0	0
20	Nagaland	0	0	0	0	10	2	1	0	10	0
21	Odisha	33	2	242	42	79	0	143	0	195	1
22	Punjab	0	0	1	0	1	1	0	0	10	0
23	Rajasthan	0	0	0	0	0	0	0	0	0	0
24	Sikkim	0	0	0	0	0	0	0	0	0	0
25	Tamil Nadu	53	0	51	0	127	2	147	0	231	1
26	Telengana	8	1	4	0	11	0	20	0	55	0
27	Tripura	28	4	98	1	90	0	59	0	61	2
28	Uttar Pradesh	2	0	0	0	0	0	0	0	0	0
29	Uttarakhand	351	42	410	73	693	93	323	25	235	21
30	West Bengal	342	75	174	39	165	40	140	35	82	11
31	Andaman & Nicobar Islands	0	0	0	0	0	0	0	0	0	0
32	Chandigarh	0	0	0	0	0	0	0	0	0	0
33	Dadra & Nagar Haveli	0	0	0	0	0	0	0	0	0	0
34	Daman & Diu	0	0	0	0	0	0	0	0	0	0
35	Delhi	0	0	0	0	0	0	0	0	0	0
36	Lakshadweep	0	0	0	0	0	0	0	0	0	0
37	Puducherry	0	0	0	0	0	0	0	0	0	0
Grand Total		**1730**	**291**	**1676**	**283**	**2181**	**254**	**1107**	**1678**	**182**	**2545**

Table 1: Japanese Encephalitis cases and deaths (2015-2019)

(National Health Profile, 2020, p.151)

Note: C= Cases, D= Deaths, P= Projected; Northeast Indian States are highlighted

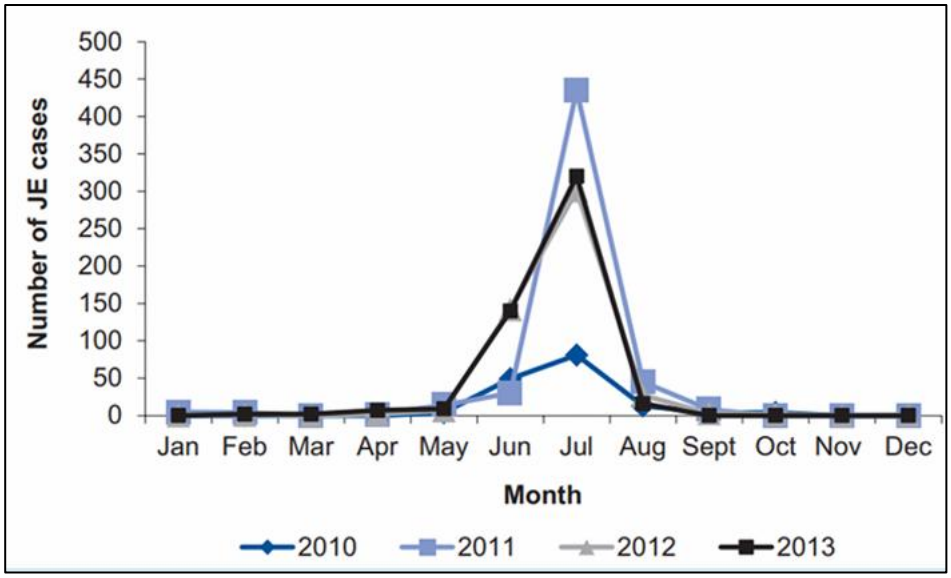

Fig 3: Seasonality of Japanese encephalitis (JE) cases from 2010 to 2013, data from the State Health Directorate of Assam **(Dev, Sharma, & Barman; 2015)**

Leptospirosis: Leptospirosis is found in at least 14 Indian states, with the highest number of cases reported in Kerala, Gujarat, Tamil Nadu, and parts of the Northeast like Assam and Meghalaya. Leptospirosis is caused by *Leptospira* bacteria — spiral-shaped organisms (spirochetes), with *Leptospira interrogans* being the most common culprit. A person can catch leptospirosis either by coming into direct contact with the urine or body tissues of infected animals — like rats, cattle, pigs, or dogs — or by touching water or soil contaminated with that urine **(Brito, Silva, et al., 2018)**. Infection usually happens when bacteria enter the body through cuts, wounds, or mucous membranes (like the eyes or mouth). Monsoon floods can easily spread contaminated water, especially from rats, increasing the risk of outbreaks. The illness often starts with flu-like symptoms: fever, headache, muscle pain, and red eyes. In some cases, people may develop jaundice, kidney or liver failure, or even bleeding in the lungs — a severe and life-threatening condition known as Weil's disease. Leptospirosis thrives in hot and humid conditions. The combination of heavy monsoon rains and poor drainage in many parts of southern and northeastern India creates the perfect environment for its spread. People working in flooded fields (like rice farmers) or living in overcrowded urban slums are especially vulnerable. With climate change causing more intense and frequent flooding especially during the monsoon, the disease is emerging in new areas too. In Kerala, after the rains, up to 30% of fever cases may be due to this disease. Also, studies show transmission of Leptospirosis in Mumbai after rainfall **(Supe, Khetarpal et al., 2018),** and in Assam also Leptospirosis cases were reported, but it is found in dogs during the rainy season **(Nath, Barman, Das et al., 2010)**.

Scrub Typhus: Scrub typhus is widespread across India — especially in the Northeast (like Assam, Nagaland, and Meghalaya), the Himalayan belt, and southern states such as Tamil Nadu and Karnataka. It's responsible for about 20–30% of fevers that doctors initially can't explain in the Northeast. The disease tends to spike after the monsoon, between July and October in tropical areas **(Xu, Walker et al., 2017)**. Scrub typhus is caused by *Orientia tsutsugamushi*, a bacterium that's passed to humans through the bite of tiny, infected chigger mites — often found in dense vegetation and scrubby areas. There's no human-to-human spread. Instead, people get infected when they're bitten by these mites, which often live on small animals like rodents and shrews **(Sharma, Masaraf et al., 2015)**. These mites are especially active in humid, rural areas with a lot of grass or low shrubs. The infection typically begins with fever, headache, body aches, and sometimes a rash. A dark scab, called an eschar, often appears at the site of the mite bite. In severe cases, it can lead to serious complications like pneumonia or inflammation of the brain (meningitis). These mites thrive in warm, damp environments like forest edges and scrublands, which are common across the tropical Northeast. After the rains, conditions become perfect for mite breeding, increasing the risk of transmission. People working in farms, forests, or overgrown areas are the most at risk.

Kyasanur Forest Disease (KFD): KFD is caused by the **Kyasanur Forest Disease Virus (KFDV)** — a member of the flavivirus family (which also includes dengue and Zika). The virus is primarily spread through the bite of infected forest ticks, especially *Haemaphysalis spinigera and is also known as "Monkey Fever".* These ticks live in forested areas and latch onto humans who enter these zones. The warm, moist climate of tropical forests and grasslands helps ticks thrive. As forests are cleared for farming or development, the boundary between humans and tick habitats shrinks —increasing exposure and risk of outbreaks. Monkeys, rodents, and small mammals act as natural reservoirs. People can also get infected by handling sick animals or touching infected carcasses, especially monkeys. Symptoms usually begin with high fever, headaches, and muscle aches. Some cases develop bleeding symptoms, and the disease can be fatal in about 3–10% of cases. Although KFD is endemic to the Western Ghats, particularly in Karnataka (notably Shimoga district), Maharashtra, Goa and Kerela, where around 400-500 cases are reported every year **(Walsh, Mor, Maity & Hossain; 2019)**. In recent years, outbreaks have been reported in new regions, driven by deforestation and more people entering previously undisturbed forest zones, especially the North-eastern states.

Malaria: A very common disease in northeast India that appears frequently in the region is Malaria. It mainly infects people after the prolonged monsoonal floods, especially in the

floodplains. In India, especially regions exposed to water mainly on the river banks, lakes, and valleys are prone to this type of mosquito-borne disease. A total of 1169261 cases were registered on 2015, 1087285 cases in 2016, 844558 in 2017, 429928 in 2018 and in 2019, it is projected to reach 334685 cases. The mortality cases were accordingly 384, 331, 194, 96, and in 2019, it will be 50 deaths as per the projection **(National Health Profile, 2020, p.143)**.

Rabies: Indigenous communities often have a long history of living closely with animals, especially dogs, cats, and birds. Dogs have traditionally been used in hunting and for alerting owners about wild animals. But dogs are also responsible for about 95% of rabies cases in India. Rabies is caused by the rabies virus, part of the *Lyssavirus* family. The virus spreads mainly through the bites of infected animals. It can also be transmitted by other animals like cats, monkeys, jackals, or foxes, if their saliva enters a cut or comes into contact with the eyes, mouth, or nose. Rabies usually starts with fever and unusual sensations at the bite site, but quickly worsens into agitation, confusion, fear of water (hydrophobia), and paralysis. Tragically, once symptoms appear, the disease is almost always fatal. India bears the world's highest rabies burden, where every year around 20,000 deaths take place **(Radhakrishnan, Vanak et al., 2020)**. States like Uttar Pradesh, Bihar, and Assam are among the worst affected. Warm weather supports large, free-roaming dog populations, which raises the risk of bites and infections. In rural areas, especially in the Northeast and parts of the South, people often can't reach healthcare facilities in time to get post-exposure vaccinations (PEP). Additionally, monsoons can displace wild animals, increasing the chances of human-wildlife interactions and new sources of infection.

Brucellosis: The contribution of animal farming (also known as livestock and poultry rearing) to the economies of the Northeast India states is significant at the household and rural economy level. The warm climate in these regions supports year-round animal farming. Combined with poor hygiene practices and the consumption of raw dairy, increases the spread of a bacteria called **Brucella** (most commonly *B. Melitensis* and *B. abortus), causing* Brucellosis. It spreads mostly through contact with infected livestock. People can catch brucellosis by handling infected animals (like goats, cattle, or sheep) or their body fluids during birthing or milking, eating unpasteurized milk or dairy products or by inhaling bacteria in places like slaughterhouses or animal sheds. The disease often causes fever, body aches, joint pain, and fatigue. If untreated, it can turn chronic and lead to serious issues like arthritis, spinal infections, or even heart complications. Around 3–3.5% of people in high-risk groups — such as farmers and veterinarians — are estimated to be infected. However, it's underreported, mainly because

of limited diagnostics in rural areas. Also, in recent years, it has been observed that flooding during the monsoon can also spread animal waste, contaminate water sources and heighten the risk of outbreaks of Brucellosis.

Nipah Virus: The Nipah virus (NiV) is a deadly paramyxovirus that first emerged in Asia in the late 1990s. The virus is carried by fruit bats (*Pteropus* species), which are natural hosts. Tropical regions with dense forests and fruit trees are home to large fruit bat populations. As forests are cleared or fragmented, bats move closer to towns and villages- increasing the chances of spillover. The warm and humid conditions also allow the virus to survive longer in the environment, especially in food sources like fruit or palm sap. Humans can get infected in several ways, i.e. by coming into contact with infected bats or pigs, by consuming fruits or palm sap contaminated by bat saliva or droppings or through human-to-human transmission via respiratory droplets or body fluids — especially in close-contact settings like hospitals or homes. The illness often starts with fever, headache, and breathing difficulty **(Alam, 2022)**. It can rapidly progress to brain inflammation (encephalitis) and coma. Nipah is extremely dangerous, with a mortality rate of 40–75%, depending on the outbreak and healthcare access **(Singh, Dhama et al., 2019)**. India has seen several deadly outbreaks, for instance, in Kerala (2018, 2019, and 2021) and in West Bengal (2001 and 2007). The Northeast states are at growing risk because, in recent years, Horticulture has expanded significantly due to the region's diverse Agro-climatic conditions. States like Sikkim, Assam, and Meghalaya have seen rapid growth in the cultivation of fruits (pineapple, orange, kiwi). This has also created ideal conditions for the proliferation of rich bat populations and expanding human activity in forested areas.

ZOONOSES SUSCEPTIBILITY AND THE NORTH EAST INDIAN STATES

The Northeastern states of India experience a humid subtropical to alpine climate, marked by heavy monsoon rains from June to September. Summers are warm and wet, while winters are cool and dry. The region's varied elevation creates diverse microclimates, supporting rich biodiversity and dense forests. It also boasts of rich vegetation cover, including tropical rainforests, deciduous forests, and alpine meadows. High rainfall and diverse terrain support dense forests with bamboo, sal, teak, and oak. The region is a biodiversity hotspot, home to rare plant species and vital for ecological balance, traditional livelihoods, and climate regulation It also hosts diverse fauna due to its varied ecosystems and rich forests. It shelters rare species like the red panda, hoolock gibbon, clouded leopard, and one-horned rhinoceros. Numerous

endemic birds, reptiles, and insects thrive here, making it a key biodiversity hotspot and vital for wildlife conservation in India.

Shakespeare (2009) observes that many emerging pathogens are seen in tropical and subtropical areas, because either the relationship of humans with animals is closer or environmental factors such as extreme heat encourage workers to be less careful with their use of protective clothing. High levels of ambient environmental heat and humidity allow pathogens to survive in the environment for longer and multiply faster on a susceptible host. The presence of humans in previously undisturbed rainforests or other ecosystems can lead to circumstances in which exposure to novel pathogens occurs.

It is in this context, the hazard mapping and susceptibility analysis for any future outbreak of zoonotic diseases in the Northeast becomes important. A state-level analysis of the top five densely populated states of North East India, notably Assam, Tripura, Meghalaya, Manipur and Nagaland, in descending order of their population density has been made below.

I) Assam

Located in the Brahmaputra and Barak River valleys, Assam is largely a flat alluvial plain with fertile soils and low hills in the south and east. It has a humid subtropical climate with heavy monsoons (June–September), hot summers, and mild winters. It has rich tropical, moist deciduous and evergreen forests. Tea gardens and grasslands are widespread. Assam is also home to the one-horned rhinoceros, wild buffalo, swamp deer, and several bird species. Kaziranga and Manas are key wildlife sanctuaries. In recent years, due to Climate Change, increased flood frequency, riverbank erosion, and erratic rainfall, agriculture and habitats have been affected tremendously. The major natural hazards include seasonal floods, riverbank erosion, and occasional earthquakes. The population density and Urbanization reached more than ~398/km² **(Government of India, 2011)** in major cities like Guwahati, Dibrugarh, Jorhat, and Tinsukia. Assam is also a corridor for illegal animal trade and a major transit route for wildlife trafficking due to its international borders.

Potential Zoonoses:

1) **Emerging/Re-emerging Viral Hemorrhagic Fevers** (e.g., Nipah Virus, Dengue, Chikungunya, theoretical KFD-like virus): Nipah virus has potential for emergence in districts bordering Bangladesh, or areas with large *Pteropus* bat roosts near fruit orchards and pig farms (e.g., Dhubri, South Salmara-Mankachar, Goalpara, Kamrup Rural, Nagaon, potentially areas around Guwahati). Similarly, Dengue/Chikungunya

has seen expansion into new urban/peri-urban areas as vector *Aedes* mosquitoes adapt to climate change and human movement. Hotspots in densely populated urban centers (Guwahati, Dibrugarh, Silchar, Jorhat) and then spreading along transport routes to smaller towns. Monkey fever and its variants (KFD-like), while not endemic, hypothetical emergence can be postulated in highly forested districts like Dima Hasao, Karbi Anglong, or parts of Jorhat, Golaghat and Goalpara district, particularly near areas of forest encroachment or logging, that are infested with the menace of monkeys. The key drivers of vector expansion, altered bat behavior, which can be attributed to climate change, aided by urbanization, encroachment of forest and scrublands. The illegal wildlife transit route also puts the state at high risk.

2) **Emerging/Re-emerging Influenza Viruses/ Novel Coronaviruses** (e.g., SARS-CoV-like, Avian Influenza H5N1/H7N9, Swine Flu variants): Exploding livestock population due to intensified farming creates pathogen mixing vessels, which, with the existing impacts of climate change, causes stress on wildlife and alteration in migratory bird routes. Besides, the illegal wildlife trade poses risks of the introduction of novel strains from wild birds/mammals in the state. The most likely areas are those with intense poultry/pig farming, live animal markets, and high human-animal interaction (e.g., poultry belts in Barpeta, Nagaon, Kamrup Rural, areas surrounding Guwahati and other large towns).
3) **Leptospirosis**: increased flooding and water contamination (post-floods) coupled with poor sanitation and agricultural practices poses the risk of spread of Leptospirosis, particularly in flood-prone districts with extensive paddy cultivation and livestock (e.g., Lakhimpur, Dhemaji, Morigaon, Goalpara, Jorhat).
4) **Scrub Typhus/Other Rickettsial Diseases**: Assam has seen broad distribution of diseases related to Rickettsial diseases, but hotspots remain in rural/peri-urban areas with scrub vegetation, agricultural fields, and close human-rodent interaction (e.g., districts in Lower Assam and central Assam). Expansion of rodent population, loss of ecological buffers, coupled with expansion of vectors (infected fleas & infected trombiculid mites) have caused the rise in cases.
5) **Anthrax/Brucellosis**: The Exploding livestock population, causing changes in grazing patterns and stress on animals, has posed a significant risk in the spread of Brucellosis-related diseases. Cases of localized outbreaks have come from areas with high livestock density, that experience flooding or pasturing in degraded lands, coupled with poor veterinary practices and traditional animal husbandry- notably in Nagaon, Morigaon, Darrang and Kamrup districts of Assam.

II) Tripura

Tripura is the only state in the Northeast that has a humid subtropical climate with moderate to heavy rainfall and short winters. It is surrounded by hilly terrain with valleys and plains, bordered by Bangladesh on three sides. The unique climate has contributed to dense tropical evergreen and moist deciduous forests. Rubber and bamboo plantations are common. In terms of its faunal characteristics, elephants, leopards, wild boars, and diverse bird and reptile species abound in its forests. Tripura has seen significant biodiversity loss due to deforestation for agriculture, rubber plantations, and settlement. There is also significant cross-border illegal trade, which includes wildlife. Frequent floods, crop failures, and deforestation-related erosion issues are the major hazards of the state. The population density is high, and urbanization is growing, with Agartala as the key urban center.

Potential Zoonoses:

1) **Nipah Virus:** Extreme proximity to the endemic zone in Bangladesh, shared bat populations, human consumption of potentially contaminated foods and climate change effects influencing bat foraging patterns, which makes Tripura highly vulnerable to Nipah virus. There is a significant risk in districts bordering Bangladesh (e.g., West Tripura, Sepahijala, Gomati) due to known annual Nipah outbreaks in nearby Bangladesh. Areas with date palm sap collection or extensive fruit orchards near human habitation are particularly vulnerable.
2) **Avian Influenza/Swine Flu variants:** Exploding livestock population (intensive farming), illegal cross-border trade of poultry/pigs can contribute to the next outbreak in areas with dense poultry and pig farming, often in close proximity to human settlements, especially near the Bangladesh border, namely the districts of Dhalai, Sipahijala, Khowai and Gomati.
3) **Leptospirosis:** Widespread in low-lying, agricultural districts of Tripura, namely West Tripura, South Tripura, Gomati and Sipahijala, especially in post-monsoon and after floods. The main factors are climate change-induced flooding, rising population density and accompanying poor sanitation conditions.
4) **Scrub Typhus:** Human encroachment and biodiversity changes have caused an increase in breeding grounds across the rural and peri-urban areas of Tripura, notably the district of West Tripura, which is one of the most densely populated districts in the state, followed by North Tripura and South Tripura

III) Meghalaya

Meghalaya, a hilly state with central plateaus and deep valleys, is known for its limestone caves and waterfalls. It has mild summers and cool winters but experiences heavy rainfall with one of the world's highest rainfall records (Mawsynram). The vegetation cover is characterized by dense subtropical forests, with pine, oak, and a wide variety of orchids and medicinal plants. It also has a rich diversity of fauna with leopards, barking deer, elephants, and rare amphibians. The important bird species include the grey peacock pheasant. Over the years, the impact of climate change has led to increased landslides, altered rainfall patterns, and drying springs that affect agriculture and water supply. The population density is moderate i.e., ~132/km² **(Govt. of India, 2001)**, with Shillong as the main urban center.

Potential Zoonoses:

1) **Nipah Virus:** Proximity to Bangladesh (spillover risk), presence of reservoir bats, climate change (altered bat behavior), human population encroachment has the potential to cause the outbreak of Nipah virus in districts bordering Bangladesh (e.g., South West Khasi Hills, South Garo Hills) or areas around Shillong with documented bat presence, especially where local communities consume fruits potentially contaminated by bats or engage in small-scale pig rearing.
2) **Scrub Typhus:** Although Rickettsial Diseases are fairly widespread, particularly in rural and semi-urban areas with mixed vegetation and rodent populations. Cases have come across from East Khasi Hills, Ri Bhoi, and Garo Hills districts of Meghalaya. The key drivers are population growth (encroachment into scrubland), biodiversity loss (rodent dynamics), and climate change (vector distribution).
3) **Japanese Encephalitis (Emergence/Expansion):** With growing population and an increase in agriculture and livestock farming, especially pig rearing, cases of JE have emerged in Meghalaya, primarily from the valleys and plains areas with paddy cultivation and pig farming (e.g., Ri Bhoi district, plains areas of Garo Hills). Climate change may, in the future, extend the transmission season or elevate endemicity.

IV) Manipur

Manipur is a mountainous state with a central valley (Imphal Valley) surrounded by hills. It experiences a mild to humid subtropical climate with adequate rainfall and a marked winter. Famous for its Sangai deer (brow-antlered deer), pangolin, and many wetland bird species, it is covered in tropical moist deciduous forests and bamboo groves; the famous Loktak Lake supports rich aquatic vegetation, whose ecosystem is threatened by rising temperatures and human encroachments by farming. Manipur is also a major hub for illegal wildlife trade due to

its border with Myanmar and connectivity to Southeast Asia. High density of population is found in Imphal Valley, and the trend is growing in rural hill areas.

Potential Zoonoses:

1) **Nipah Virus:** Geographic proximity to Southeast Asian "hot zones," and the high risk of introduction via illegal wildlife trade, local bat populations and human-animal interface make Manipur a region of potential, although there is less direct evidence. The general presence of *Pteropus* bats and shared border with Myanmar (which also has NiV risk) suggests risk, especially in the district of Tengnoupal, Chandel, Churachandpur, Kamjong, Ukhrul and beside the central valley and areas with orchards and pig farms.
2) **Novel Viruses, paramyxoviruses & Coronaviruses**: These deadly viruses could emerge at markets or points of contact related to illegal wildlife trade, especially in densely populated areas like Imphal East and Imphal West district, or border towns like Moreh in Tengnoupal district. A small cluster of cases could quickly spread within the dense Imphal Valley. The main driver for such viruses will be Illegal wildlife trade, i.e., mixing of species, stress on animals, direct human exposure to exotic pathogens, and also, to a great extent, population density and mobility facilitating rapid spread.
3) **Parasitic Zoonoses** (e.g., Paragonimiasis, Taeniasis/Cysticercosis)**:** Existing cultural practices, linked to specific dietary practices like consumption of undercooked pork in rural and semi-urban communities throughout the state, aided by pig farming, poor sanitation, have caused the presence of parasitic eukaryotes in Manipur.
4) **Japanese Encephalitis:** It is endemic in the Imphal Valley and other plain areas with paddy fields and pig farming, with July and August usually being the peak months for JE cases, with the number of cases gradually declining by October and November. Climate change has influenced the survival of the vector, while Population density with pig rearing creates the breeding factors.

V) Nagaland

Nagaland, with its general mountainous terrain with narrow valleys and high ridges, forms part of the Naga Hills. It is also characterized by subtropical and temperate climates with moderate rainfall and cool winters. Tropical and subtropical forests, with bamboo, oak, rhododendron, and coniferous species in higher altitudes, characterize its vegetative cover, while in terms of its faunal realm, the Clouded leopard, stump-tailed macaque, and hornbills are widespread. Over the years, there has been a loss of its rich biodiversity due to traditional hunting practices **(Longchar, 2022)** and significant deforestation **(Deori, 2005)**, especially due to shifting

cultivation and timber extraction. Also, Nagaland is a major transit route and source for wildlife products due to its proximity to Myanmar and rich biodiversity.

Potential Zoonoses:

1) **Japanese Encephalitis (Expansion/Increased Endemicity):** Climate change could potentially expand suitable mosquito habitats and the existing agricultural practices of Pork farming pose the risk of spread of JE in valleys and plains (notably Dimapur) in Nagaland.
2) **Novel Viruses** Illegal wildlife trade, direct human-wildlife contact, mixing of species, particularly bat-borne or pangolin-borne, coupled with the overall biodiversity loss and human encroachment into deep forests, pose the dangers of the spread of novel viruses. Special high risk exists at collection points, transit hubs (Dimapur), and markets where illegal wildlife is sold. And any initial spillover could occur in rural forest-fringe communities involved in hunting/trade.
3) **Scrub Typhus/Rickettsial Diseases:** It is almost widespread in forested and scrubland areas, notably the districts that have undergone significant deforestation and jhum cultivation like Kohima, Phek, Zunheboto and Mokokchung Districts of Nagaland. They particularly affect communities engaged in agriculture, forestry, or foraging. Human encroachment into natural habitats, biodiversity loss and rodent population explosion are other notable factors.
4) **Emergence of unknown agents:** Given its rich, relatively unexplored biodiversity and wildlife trade routes, Nagaland has a theoretical risk of novel zoonotic pathogens that are yet to be identified.

CONCLUSION

Deforestation, hunting and consumption of species are widely recognized to negatively impact biodiversity. Some fauna can absorb those infectious pathogens but deforestation and hunting may bring danger to their existence due to habitat loss. To better understand these effects, Morand and Lajaunie published a report in Frontiers of Veterinary Science, entitled " Outbreaks of Vector-Borne and Zoonotic Diseases are Associated with Changes in Forest Cover and Oil Palm Expansion at Global Scale" where changes in forest cover around the world between 1990 and 2016 are been observed and then compared these results to the local population densities and outbreaks of vector-borne and zoonotic diseases **(Morand & Lajaunie, 2021)**. Several prior studies had claimed that both afforestation and palm oil plantations likely play a role in further spreading disease vectors. Confirming past hypotheses, they found that both

deforestation and afforestation had significant correlations to disease outbreaks. They found a strong association between deforestation and epidemics (such as malaria and Ebola) in tropical countries like Brazil, Peru, Bolivia, the Democratic Republic of Congo, Cameroon, Indonesia, Myanmar and Malaysia. They also found a significant increase in disease outbreaks in countries with expanding palm oil plantations. These areas appeared particularly susceptible to mosquito-borne diseases like dengue, Zika, chikungunya and yellow fever. Besides, consumption creates a risk of pathogenic transmissions to humans from animals, insects, birds, etc. More research should take place for identification of the different pathogens found in animals, birds, insects, etc, especially their characteristics, the pattern of transmission of pathogens (if exist) needs to be identified to minimize the outbreak risk.

In Northeast India, Deforestation has already been linked to a rise in cases of malaria epidemics, but the global consequences of deforestation and forest cover changes on human health and epidemics have not been studied in detail. As mentioned earlier, northeast India has a diverse culture, and also due to its proximity to the nearest Southeast Asian countries, it is exposed to the illegal animal trade markets, escalating the risk of reducing its diversity as well as increasing the threat for new pathogenic transmission, which can bring the entire globe to a standstill like COVID-19. So, special attention should be given by the national and international authorities to monitor this issue and take precautionary steps to from the reemergence of such hazardous situations.

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DATA AVAILABILITY

The data taken for this study is available in open-source platforms.

DECLARATIONS OF CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work entitled “Northeast India and its Vulnerability to Zoonotic Diseases: A Review”.

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