ISSN: 0973-4929, Vol. 16, No. (1) 2021, Pg. 304-312

Current World Environment

www.cwejournal.org

Environmental Concerns for Emergence and Reemergence of Novel Viral Infectious Diseases: Implications For Sars-Cov-2 and Other Pathogens

KUMAR MANOJ

Department of Botany, Marwari College, Tilka Manjhi Bhagalpur University, Bhagalpur, 812007, Bihar.

Abstract

The existing COVID-19 pandemic is an anthropogenic disaster which looked inevitable, because despite repeated natural warnings no attention was paid to them. Recently many viral zoonotic infections – caused by SARS-CoV-1, Ebola and Nipah, to name a few – happened that became public health emergency. The most recently discovered zoonotic SARS-CoV-2 is responsible for the contemporary humanitarian disaster. When a virus undergoes zoonotic transmission, the humans begin to respond urgently to its testing and treatment, giving least attention to the actual cause behind the transmission. To prevent future outbreaks, and possible pandemics, it is indispensable to understand the reasons behind emergence of new infectious diseases in human beings. Some most likely reasons for emergence and reemergence of novel zoonotic infections include deforestation, land use change, wildlife trade, bush-meat consumption and rapid increase in international travel. This article attempts to explore and discuss the factors that trigger emergence and reemergence of novel infectious diseases, with special emphasis on SARS, in human beings.

Article History
Received: 24 April 2020
Accepted: 14 December 2020

Keywords
COVID-19;
Deforestation;
SARS-CoV-2;
Wildlife Trade;
Zoonotic Infections.

Introduction

A great challenge in biology is finding the truth behind unsolved mystery of the emergence of zoonotic pathogens. Many pathogens emerged and reemerged in the past; and estimates suggest that one new pathogen emerged every 18 months. Majority of the new pathogens had zoonotic origin in wildlife.[1] Environmental changes play a great role in the emergence of certain infectious diseases and their possible reemergence, mostly in regions with high biodiversity and long term unresolved problems about environmental and socioeconomic issues. There is a relationship between outbreaks of infectious diseases and environmental changes such as deforestation, habitat fragmentation, bush-meat consumption and urbanization.[2]

CONTACT Kumar Manoj kumarmanojenv@gmail.com Department of Botany, Marwari College, Tilka Manjhi Bhagalpur University, Bhagalpur, 812007, Bihar.

Doi: http://dx.doi.org/10.12944/CWE.16.1.30

The emergence of zoonotic diseases and their expansion are particularly sensitive to ecological changes and population movements.[1] The contemporary COVID-19 (coronavirus disease-2019) pandemic, most likely, is the manifestation of behavior of the human beings towards the nature. Humans favor consuming wild animals for food or their products, giving rise to the destructive wildlife trade. At the same time there is uncontrolled habitat destruction of the wildlife. These actions bring humans, wild animals, and also domestic animals closer, risking the chances of zoonotic transfer of pathogens from animal-to-human and consequently human-to-human, through a 'chain reaction'. Coupled with the above mentioned activities is the globalization, which brings humans even closer, that makes the possibility of transfer of infectious pathogen, sometimes deadly, much higher. For example, as per the recent assessment of the United Nations World Tourism Organization, global international tourist arrivals in 2018 grew 6% totaling 1.4 billion.[3] A disease that originated in Wuhan (Hubei province, China) quickly spread across the earth, and now almost all countries across the globe are affected by the SARS-CoV-2 (severe acute respiratory syndrome coronavirus-2), the causative agent of the COVID-19 pandemic, prompting almost all laboratories around the globe to find a potential cure against the virus SARS-CoV-2. Meanwhile, equally important are the studies, discussions and dialogues about the environmental reasons behind the emergence, and possible reemergence, of infectious disease in humans to prevent outbreaks and potential pandemics in future. This article is a step in this direction to present some environmental concerns for the emergence and reemergence of novel viral infectious diseases in humans.

Discussion

There is a risk of emergence of novel infections from the natural habitats into the increasing human population.[4] Deforestation likely correlates with the emergence of infectious diseases as reported in some recent publications.[5,4] Deforestation may cause zoonotic infections in human populations, particularly living close to forest margins, as there is increasing likelihood for the people to come in contact with wild animals acting as reservoir of diseases.[5] For example, emergence of Ebola virus disease outbreaks (2004-2014) in West and Central Africa have been linked to deforestation induced habitat fragmentation and land cover change followed by disease spillover from wildlife reservoirs.[6,7,5] Another scientific report published in 2017, using remote sensing techniques, linked recent forest losses to Ebola virus disease outbreaks in West and Central Africa; and suggested that prevention of forest loss could decrease the likelihood of outbreaks in future.[8] The World Health Organization in its report on the "*origins of the 2014 Ebola epidemic*" mentions that the 2014 West Africa's Ebola epidemic began in Guéckédou district (Guinea), where much of the region's surrounding forest area were destroyed due to mining and timber operations by foreign companies. The report further suggests that forest loss, approximately more than 80%, in the affected area potentially brought infected wild animals and bats into closer contacts with the human settlements, causing epidemic to occur.[9] Fragmented forests coupled with higher human population density have also been linked to Nipah virus spillovers.[10] The zoonotic emergence of Nipah virus in Southeast Asia was linked to large scale deforestation of tropical rainforests for pulpwood and industrial crop plantations. The habitat destruction of wildlife led the fruit bats to migrate to the cultivated fruit orchards containing pig farms. This exposed pigs to the excreta and other secretions of bats. From infected pigs, the virus spread to the humans.[11,12] Deforestation induces rise in contacts with pathogen-infected people, reservoir species or the vectors.[2,13] Forest loss can also facilitate the disease to spread to non-forest areas.[8] A brief summary of some viral infectious diseases emerging possibly due to deforestation and other environmental factors is given in Table 1. The range and diversity of disease causing pathogens likely shows a relationship with the hosts they prefer to live in, and likewise as the species richness, among mammalian orders, increases the number of mammals as hosts for zoonotic infections also increases. Thus, while species diversity may decrease due to habitat loss and fragmentation, the encroachment of species-rich natural habitats by humans may increase the chances of exposure to new infectious parasites from wildlife. Increase in habitat fragmentation intrinsically increases the microbial hazard.[4] 'Dilution effect hypothesis' postulates that pathogen prevalence is negatively correlated with increased species diversity.[1]

Table 1: Some environmental concerns for the emergence and possible reemergence of zoonotic infectious diseases in humans

S. no.	Etiological agent or name of the disease	Host or reservoir	Mode of exposure	Likely reasons for emergence or reemergence in humans
i	Hantavirus	Rodents	Direct contact	Disturbed rodent habitats due to deforestation and extensive agricultural land use conversion; urbanization; recreational activities
ii	Yellow fever	Non-human primates	Vector borne	Deforestation and expansion of human settlements especially along the edges of the forests; urbanization; hunting
iii	HIV	Non-human primates	Direct contact	Deforestation and human intrusion into forests; poaching and slaughtering or butchering of wild animals; adaptation by parasites
iv	Ebola virus	Non-human primates; bats	Direct contact	Deforestation; outbreaks along forest edges; logging; agricultural expansion; natural fauna alteration; poaching and butchering; bush-meat consumption
v	Nipah virus	Bats; pigs	Direct contact	Deforestation; habitat fragmentation; fruit orchards and pig population on forest border
vi	Zika virus	Non-human primates	Vector borne; sexual transmission	Deforestation and urbanization associated with elevated Zika virus outbreak; correlation between less forest cover and higher rates of Zika virus-linked cases; climate change
vii	SARS-CoV-1	Bats; masked palm civets	Respiratory droplets; Direct contact	Mixing of bats, masked palm civets and other mammals during harvesting, transport and marketing (wildlife trade); game meat consumption
viii	SARS-CoV-2	Bats; Malayan pangolins (most likely)	Respiratory droplets; Direct contact	Mixing of bats, pangolins and other mammals during harvesting, transport and marketing (wildlife trade); game meat consumption

Source: [i] = reference[1,2]; [ii, iii, vii] = reference[17]; [iv] = reference[17,2]; [v] = reference[10,11,12,17]; [vi] = reference[13,2]

Deforestation is of great concern, particularly in tropical rainforests that contain major part of the earth's biodiversity. About 80% of the earth's land-based species live in forests.[14] As per the assessment of WWF, the world is losing annually about 18.7 million acres of forest, and if the current trends continue between 2010 and 2030, the world could lose up to 420 million acres of forest; Amazon, in the last 50 years, alone has lost about 17% of its forest, mainly due to agricultural conversions.[14] The recent data about deforestation, reported by The Guardian, points out that the rate of forest loss has reached 64 million acres or 26 million hectares per year, showing rapid rise in loss in the 5 year span between 2014 and 2018; the tropical primary forests have lost 4.3 million hectares cover per year; the major tropical forest regions of the world – Africa, Latin America and Southeast Asia – markedly showed rise in annual rate of loss of tree cover in the period 2014-2018 as compared to 2001-2013; in 2014-2018 period,

the average annual tree cover loss for Asia was slightly less than 4 million hectares, for Africa was more than 4 million hectares, and for Latin America and Caribbean region was much above 5 million hectares; the Africa showed a dramatic rise, where the rate of deforestation increased from less than 2 million hectares per year (on an average) in 2001-2013 period to more than 4 million hectares a year in 2014-2018. Agricultural conversion is the major cause of deforestation while illegal logging is the major reason behind forest degradation.[15] The unhealthy eating habits of consumers are also a major driving force behind deforestation. For example, demand for meat results in demand for cheap animal feed that leads to deforestation. Another factor is the demand for timber. For example, African timber is exported to China.[16] Deforestation may lead to more frequent contacts between humans and infected wild animals harboring pathogens, increasing the risks of zoonotic transmissions. There are many plausible explanations for this to happen – the possibility of contacts increases when the hunters/ people travel further into the forest; in fragmented forests the potential reservoirs of pathogens can increase in density because deforestation influences movement and abundance of animal reservoir of pathogens through disruption of animal movements; and anthropogenic activities of timber cutting and forest disturbance seriously influence behaviors of the wider mammalian fauna.[8]

Certain behaviors of human beings provide opportunities for direct human-wild animal contact18 which is used by opportunistic pathogens to spillover from animals to humans. For examples, Ebola virus outbreaks are associated with bush-meat consumption and the transmission of Chagas disease occurs due to consumption of meat of wild animals or their blood.[2] Karesh *et al*.[19] had published a salient perspective on wildlife trade and emergence of global infectious diseases. According to the authors, wildlife trade not only provides a mechanism for disease transmission that gives rise to human disease outbreaks but also threaten native wildlife population and the overall ecosystem health. Wild mammals, reptiles and birds are traded through the trading centers, where they come in contact with the people and with many other species as well. It was suggested that the wildlife trade annually results in at least some multiple of 1 billion direct and indirect contacts among wild animals, human beings and domestic animals. The wildlife trade not only exposes wild animals to human beings but also to domestic animals and native wildlife scavengers that consume the wastes of traded animals. It is almost impossible to do precise quantification of the global wildlife trade, but some rough estimates indicate they run into tens of millions for food or use in traditional medicines. The prevalence of many viruses such as HIV, Ebola and SARS-CoV-1, in humans, can be traced to their presence in animals such as non-human primates, great apes and civets. There are three important aspects in the cross-species spillover of pathogens. First, during the capture of wild animals, humans come in contact with them. Second, the wildlife markets are hubs that bring a number of humans as well as many wild animal species together, increasing contact rates between wildlife-humans as well as among humans. Third, animal species can come in contact during transportation; the rapid transportation infrastructure of modern world would serve to rapidly transmit the infectious disease among animal species and also from human-to-human.[19] An earlier paper of Taylor *et al*.[20] identified 1415 species of infectious pathogens affecting humans, and a whopping 868 (68%) of them were found to be zoonotic. The authors suggested that zoonotic pathogens have twice the chances to be associated with emerging diseases than non-zoonotic ones.[20]

Currently the world is facing COVID-19 pandemic because of the recently emerged virus SARS-CoV-2. Close to two decades back another SARS pandemic had occurred caused by the virus SARS-CoV-1. Although the two pandemics happened due to different coronaviruses, they share environmental characteristics. For examples, both are outcomes of the zoonotic infections and emerged in the wildlife animal markets of China. The SARS disease of 2002-2003 began in animal markets in China which sold exotic animals such as bats, masked palm civets and raccoon dogs for food.[21] SARS-CoV-1, first emerged in the population of southern China in 2002 November[22] and had a zoonotic origin – cross-species animal-to-human transmission that later adapted to undergo human-to-human transmission. It appeared horseshoe bats were natural reservoirs of SARS-CoV-1 and palm civets, and probably some other mammals, served as amplification hosts.[23] The coronavirus was identified in March 2003, and most of the early cases were found to be limited to

the Guangdong (a province in China) with a unique dietary culture savoring freshly slaughtered game meat.[24] Initial investigation suspected masked palm civets (*Paguma larvata*), raccoon dogs (*Nyctereutes procyonoides*) and ferret badgers (*Melogale spp*.) as primary source of the virus. The packed caging of several species of mammals, including bats, and the utter disregard of effective biosecurity measures to handle and butcher animals in live animal markets perpetuated the infection of many species including animals mentioned above.[25] The first index cases of SARS-CoV-1 in late 2002 in Guangdong, China, were several food handlers, particularly those who were involved in handling, killing or butchering the exotic animals for food. Animal traders from many live animal markets in Guangdong tested positive for the SARS-CoV-1.[26] In early 2003, subsequent outbreaks occurred in Hong Kong, Hanoi, Singapore and Toronto. These early outbreaks occurred due to one index patient who got the viral infection in Guangdong and subsequently travelled to Hong Kong.[22] The coronaviruses closely related to human SARS-CoV-1 were later isolated from many animals sold in the live animal markets including palm civets, suggesting wet-market involving transmission of SARS-CoV-1. Subsequently, SARS-CoV-1-like coronaviruses were isolated from species of Chinese horseshoe bats living in the wild in southern China and Hong Kong.[26] Thus, phylogenetic analysis indicated that the virus most likely originated from bats, was first transmitted to palm civets and then to human population at the wet-markets in southern China. In the first SARS pandemic 8096 people became infected and 774 died.[22] SARS-CoV-1 was spread by international travelers to 30 countries across 5 continents in 2003, illustrating the pivotal role of international travelers in the spread of emerging infectious diseases.[27] It is interesting to note that, shortly after a ban was imposed on the wildlife trade to curb the SARS outbreak of 2002-2003, no further naturally acquired SARS cases in humans were reported in Guangdong.[23] Additionally, massive culling drive of civets also prevented further outbreaks in the region.[28] These results reinforce the theory of animal-to-human transmission of the virus.

Very recently Andersen *et al*.[29] have proposed two scenarios about the possible origin of SARS-CoV-2 in humans: (i) natural selection occurred in an animal host before the zoonotic transfer of virus; (ii) natural selection took place in humans after the zoonotic transfer of the virus. Irrespective of the exact method by which SARS-CoV-2 emerged in humans, potential zoonotic infection of the virus in humans from animal contact cannot be denied. This is because many early COVID-19 cases were linked to the wildlife market in the Wuhan city (Hubei province, China) and most likely an animal source was present in the market.[29] The question then arises is: which animals are responsible for the emergence of SARS-CoV-2 in humans? Soon after the outbreak began, Wuhan market was cleared, and, therefore, it is a challenging task to determine the exact source of novel coronavirus in the animal population.[30] The investigations of Andersen *et al*.[29] and Zhang *et al*.,[31] however, indicate bats and pangolins as the potential reservoirs. It is possible that bats are the reservoir hosts of the progenitor of SARS-CoV-2, because bat RaTG13 coronavirus (sampled from bat *Rhinolophus affinis*) shows ~96% identity to the SARS-CoV-2. Zhang *et al*.[31] showed that like bats, pangolins (Malayan pangolins, *Manis javanica*) are also natural reservoirs of SARS-CoV-2-like coronaviruses. At the whole-genome level pangolin coronavirus is 91.02% identical to the SARS-CoV-2. After bats, pangolin coronavirus is probably the second nearest relative of SARS-CoV-2. Moreover, pangolin coronavirus is 90.55% identical to the bat coronavirus RaTG13 at the whole genome level. Andersen *et al*.[29] also suggest that Malayan pangolins contain coronaviruses that are similar to SARS-CoV-2; the receptor binding domains of pangolins and SARS-CoV-2 are very similar, suggesting that virus jumped from animal to human. Lam *et al*.[30] too identified SARS-CoV-2-related coronaviruses in the Malayan pangolins that were seized during the anti-smuggling drives in southern China, making them possible hosts in the novel coronavirus emergence; and, therefore, showing absolute monitoring of the illegal trafficking of the pangolins and their complete removal from the wildlife markets to prevent any further zoonotic outbreaks. It appears that pangolins served as an intermediate host between bats and humans in SARS of 2019-2020. This is unlike SARS of 2002-2003, where palm civets most likely were the intermediate host between bats and humans. Pangolins are the world's most illegally trafficked mammal and are heavily poached from the wild in Asia and Africa to supply booming market of traditional medicine in China; and to lesser extent in some Southeast Asian countries such as Vietnam. Moreover, their

meat is also used for consumption.[32,30] The wild animal markets have favorable environment to breed diseases with the possibility of pathogens jumping to humans. Stress, malnourishment, dehydration, filthy conditions, intermingling of species, both wild and domestic make a perfect cocktail for the creation of a new deadly disease, and having them in the urban centers certainly provide a wider dispersal mechanism. The wildlife or game meat trade is a massive risk to human health, economies as well as ecosystem health.[33] The SARS of 2002-2003 as well as 2019-2020 originated in the human-dominated wildlife markets and international travelers rapidly made them public health emergency of international concern. Researches suggesting animal origin of SARS point out to contact between animals and humans, and emergence of SARS in the wildlife markets reinforces the theory. Investigations suggest emergence of SARS-CoV-2 and SARS-CoV-1 in humans from their ancestors in wild animals such as pangolins and palm civets respectively who in turn, probably, got the viruses from bats. The SARS of 2002-2003 had relatively milder transmissibility than the SARS of 2019-2020. The trend, therefore, shows that the next SARS may be much more pathogenic. It is logically incorrect to blame bats, palm civets, pangolins, or any other wild animal for the SARS diseases in humans. These animals have their own ecological places to live which humans tend to disturb or destroy for selfish needs. In fact, the SARS-CoV-2 is an unfortunate gift by the human beings, to the human beings and for the human beings.

SARS pandemics provide some of the most recent examples of evolution of wild animal virus into a human virus. It is now paramount to do active surveillance involving screening and investigation of known and unknown viruses in wild animals as an inherent component of an integrated emerging and reemerging infectious diseases prevention of occurrence and control program.[24,28] The local hunting of bush-meat or wildlife is a very primitive practice that forms the part of many community cultures. Although, it is correct that these fundamental practices have always posed a risk for cross-species transmission of diseases in the local community, many cultural practices, however, worked to mitigate them. The modern practices, however, such as deforestation, forest fragmentation, unchecked development, coupled with increased population density have done tremendous ecological changes that favor altered pathogen-host relationships. The ecological changes, altered relationships of pathogens and hosts, globalized trade in wild animals for foods and other products along with modern transportation infrastructure which favor rapid human movement facilitate fast movement of pathogens/diseases to distant places and much higher pathogen-human contacts.[34]

It is good to see that there are some silver linings in the COVID-19 pandemic time. For examples, air and water have become relatively cleaner at some places, noise pollution has drastically plummeted and some animals, such as olive ridley turtles, have reclaimed the lands previously encroached upon by the human beings. However, these are temporary changes that are expected to revert, albeit gradually, once the pandemic ends. The anthropogenic activities would again dominate the environment. The health crisis, economical crisis, educational crisis, and overall the humanitarian crisis that the world is currently struggling with are actually the consequences of the unrestrained human actions towards the environment. Most of the scientific publications currently are busy dealing with the consequences of the COVID-19, which are actually reactionary measures. However, equally important is studies, discussions and debates on the causes behind such pandemics, epidemics or outbreaks of infectious diseases. Literatures advocate many anthropogenic factors that trigger emergence and reemergence of infectious diseases in humans that can be summarized as: deforestation; habitat fragmentation; logging; agricultural land use conversions; expanding human population, particularly, on forest fringes; urbanization; wildlife trade; hunting, slaughtering and bush-meat consumption; climate change; and international travelling. The major driving force behind deforestation is the agricultural land use conversion. The logging also causes degradation of forests. Both these events result in forest habitat fragmentation followed by forest disappearance. The international markets have demand for industrial crops and native forest timber, the business for which is controlled by foreign corporations and enterprises. The wild animals are smuggled into international markets for food, other products and traditional medicines. The unhealthy and unsustainable eating habits and unscientific traditions bring wild animals to the brink of extinction. Maximum profit from wildlife

trade can only be earned in urban centers which are actually closely packed clusters of people. Presence of unhealthy and unhygienic wild animal markets in urban centers makes a dangerous blending of emergence, reemergence and expansion of infectious diseases. The health of the earth, both in terms of environmental and socio-economical conditions, now also depends on the health of the international travelers. This makes all international airports across the globe potential hotspots of the spread of new infectious diseases.

Drastic consequences from a cause need some drastic measures to control the cause. There are already a plethora of emerging infectious diseases in nature and some of them have a very high chance of reemergence. Many epidemics occur repeatedly across the globe. The world was not prepared for the current pandemic nor can it afford another one. In this case a complete precautionary ban on wildlife trade and wildlife 'wet market' is urgently needed. The situation demands increased surveillance and outreach programs. Anyone who is involved in profiteering from game meat trade should be strictly dealt with. Therefore, equally important is providing some alternative employments to the affected people, especially rural poor who are involved in hunting, slaughtering and selling of game meat. For vulnerable people bush-meat sometimes is the only source of protein, and, therefore, provisions of alternative protein source must be dealt with. It is not that governments and international community cannot provide alternative food to them, what is required is will power, trust and peace in low-income regions of the world. Another very important thing, and probably very tough, is the change of food culture. The fact is that food behavior of love for wild animal by a group of people can threaten food security of millions of people. For example, currently there are 821 million undernourished people worldwide, which is overwhelming 10.8% of the world's population.[35] COVID-19 pandemic can seriously affect food security of millions of people around the world, and particularly the most vulnerable populations are maximally exposed to its effects. Food crisis can increase the number of undernourished people across the world. For example, food prices crisis of 2007-2008 significantly increased the number of undernourished people around the world by 14% during the two year period from 848 million people to 963 million.[36] The same situation may be faced by the millions of undernourished people this time. Demand of traditional medicine in community culture is also a major driver behind wildlife trade. Populace as well as governments must move from traditional medicines, which require killing of many wild endangered animals, to alternative treatments.

There are both global and local influences on the emergence of novel infectious diseases.[2] Studies should seek to integrate ecology and evolution to investigate host-virus interactions.[1] Anthropogenic actions disturb the ecosystem which in turn disturbs the human beings because they are an inherent part of the ecosystem. Pandemic of current magnitude can thrash all the sustainable and millennial development goals. It is central to understand that many anthropogenic actions, including wildlife trades, close the gap between wildlife-human interface, creating conditions for the pathogens to jump from wild as well as domestic animals to human beings, giving rise to emergence and reemergence of novel infectious diseases.

Acknowledgements

The author greatly acknowledges the researchers and reporters whose works were used to prepare this manuscript.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of interest

The authors do not have any conflict of interest.

References

1. Jonsson C. B, Figueiredo L. T. M, Vapalahti O. A. Global Perspective on Hantavirus Ecology, Epidemiology, and Disease. *Clin Microbiol Rev* 2010; 23(2):412-441. DOI: 10.1128/CMR.00062-09.
2. Nava A, Shimabukuro J. S, Chmura A. A, *et al*. The Impact of Global Environmental Changes on Infectious Disease Emergence

with a Focus on Risks for Brazil. ILAR J 2017; 58(3):393–400. DOI: https://doi.org/10.1093/ilar/ilx034.

3. UNWTO. International Tourist Arrivals Reach 1.4 billion Two Years Ahead of Forecasts. United Nations World Tourism Organization, PR No. PR 19003. https://www.unwto.org/global/press-release/2019-01-21/international-tourist-arrivals-reach-14-billion-two-years-ahead-forecasts. 21.01.2019 [Last accessed on 21.04.2020].
4. Wilkinson D. A, Marshall J. C, French N. P, *et al*. Habitat Fragmentation, Biodiversity Loss and the Risk of Novel Infectious Disease Emergence. *J R Soc Interface* 2018; 15: 20180403. DOI: http://doi.org/10.1098/rsif.2018.0403.
5. Rulli M, Santini M, Hayman D. *et al*. The Nexus Between Forest Fragmentation in Africa and Ebola Virus Disease Outbreaks. *Sci Rep* 2017; 7:41613. DOI: https://doi.org/10.1038/srep41613.
6. Bausch D. G, Schwarz L. Outbreak of Ebola Virus Disease in Guinea: Where Ecology Meets Economy. *PLoS Negl Trop Dis* 2014; 8(7):e3056. DOI: https://doi.org/10.1371/journal.pntd.0003056.
7. Wallace R. G, Gilbert M, Wallace R, *et al*. Did Ebola Emerge in West Africa by a Policy-Driven Phase Change in Agroecology? Ebola's Social Context. *Environ Plan A: Econ Space* 2014; 46(11): 2533–2542. DOI: https://doi.org/10.1068/a4712com.
8. Olivero J, Fa J. E, Real R. *et al*. Recent Loss of Closed Forests is Associated with Ebola Virus Disease Outbreaks. *Sci Rep* 2017; 7:14291. DOI: https://doi.org/10.1038/s41598-017-14727-9.
9. WHO. Origins of the 2014 Ebola Epidemic. World Health Organization. 24.01.2015. https://www.who.int/csr/disease/ebola/one-year-report/virus-origin/en/ [Last accessed on 21.04.2020].
10. Hahn M. B, Gurley E. S, Epstein J. H, *et al*. The Role of Landscape Composition and Configuration on Pteropus giganteus Roosting Ecology and Nipah Virus Spillover Risk in Bangladesh. *Am J Trop Med Hyg* 2014; 90(2):247–255. DOI: https://doi.org/10.4269/ajtmh.13-0256.
11. Chua K. B, Chua B. H, Wang C. W. Anthropogenic Deforestation, El Nino and the Emergence of Nipah Virus in Malaysia. *Malays J Pathol* 2002; 24(1):15-21.
12. World Organization for Animal Health. Nipah Virus. https://www.oie.int/en/animal-health-in-the-world/animal-diseases/Nipah-Virus/ [Last accessed on 21.04.2020].
13. Ali S, Gugliemini O, Harber S, *et al*. Environmental and Social Change Drive the Explosive Emergence of Zika Virus in the Americas. *PLOS Negl Trop Dis* 2017; 11(2):e0005135. DOI: https://doi.org/10.1371/journal.pntd.0005135.
14. WWF. Threats: Deforestation and Forest Degradation. World Wildlife Fund. https://www.worldwildlife.org/threats/deforestation-and-forest-degradation [Last accessed on 21.04.2020]
15. Harvey F. World Losing Area of Forest the Size of the UK Each Year, Report Finds. The Guardian. 12.09.2019a. https://www.theguardian.com/environment/2019/sep/12/deforestation-world-losing-area-forest-size-of-uk-each-year-report-finds [Last accessed on 21.04.2020]
16. Harvey F. Deforestation Damage Goes Far Beyond the Amazon. The Guardian. 12.09.2019b. https://www.theguardian.com/environment/2019/sep/12/deforestation-damage-goes-beyond-amazon [Last accessed on 21.04.2020]
17. Wilcox B. A, Ellis B. Forests and Emerging Infectious Diseases in Humans. Unasylva 224 2006; 57:11-18.
18. Bloomfield L. S. P, McIntosh T. L, Lambin E. F. Habitat Fragmentation, Livelihood Behaviors, and Contact Between People and Nonhuman Primates in Africa. *Landscape Ecol* 2020. DOI: https://doi.org/10.1007/s10980-020-00995-w.
19. Karesh W. B, Cook R, Bennett E. L, *et al*. Wildlife Trade and Global Disease Emergence. *Emerg Infect Dis* 2005; 11(7):1000-1002. DOI: https://dx.doi.org/10.3201/eid1107.050194.
20. Taylor L. H, Latham S. M, Woolhouse M. E. J. Risk Factors for Human Disease Emergence. *Phil Trans R Soc Lond B* 2001; 356(1411):983-989. DOI: http://doi.org/10.1098/rstb.2001.0888.
21. Strauss J. H, Strauss E. G. Chapter 8-Emerging and Reemerging Viral Diseases.

In: Viruses and Human Disease (2nd edition). Academic Press, Elsevier Inc.; 2008:325-343.
22. Haagmans B. L, Osterhaus A. D. M. E. Chapter 36 - SARS. In: Barrett A. D. T, Stanberry L. R. Vaccines for Biodefense and Emerging and Neglected Diseases. Academic Press, Elsevier Ltd.; 2009:671-683.
23. Boncristiani H. F, Criado M. F, Arruda E. Respiratory Viruses. In: Schaechter M. Encyclopedia of Microbiology (3rd edition). Academic Press, Elsevier Inc.; 2009:500-518.
24. Shi Z, Wang L-F. 27-Evolution of SARS Coronaviruses and the Relevance of Modern Molecular Epidemiology. In: Tibayrenc M. Genetics and Evolution of Infectious Diseases. Elsevier, Elsevier Inc.; 2011:711-728.
25. Epstein J. H. 40-Emerging Diseases in Bats. In: Miller R. E, Lamberski N, Calle P. P. Fowler's Zoo and Wild Animal Medicine Current Theory. Volume 9. Saunders, Elsevier Inc.; 2019:274-279.
26. Mei-Shang H. Chapter 59 - Severe Acute Respiratory Syndrome (SARS). In: Guerrant R. L, Walker D. H, Weller P. F. Tropical Infectious Diseases: Principles, Pathogen and Practice (3rd edition). Saunders, Elsevier Inc.; 2011:392-397.
27. Rothe C, Jong E. C. Chapter 3 - Emerging infectious diseases and the international traveler. In: Sanford C. A, Pottinger P. S, Jong E. C. The Travel and Tropical Medicine Manual (5th edition). Elsevier, Elsevier Inc.; 2017:27-35.
28. Shi Z, Wang L-F. 26-Evolution of SARS Coronaviruses and the Relevance of Modern Molecular Epidemiology. In: Tibayrenc M. Genetics and Evolution of Infectious Diseases (2nd edition). Elsevier, Elsevier Inc.; 2017:601-619.
29. Andersen K. G, Rambaut A, Lipkin W. I, *et al*. The Proximal Origin of SARS-CoV-2. Nat Med 2020. DOI: https://doi.org/10.1038/s41591-020-0820-9.
30. Lam T. T, Shum M. H, Zhu H, *et al*. Identifying SARS-CoV-2 Related Coronaviruses in Malayan Pangolins. Nature 2020. DOI: https://doi.org/10.1038/s41586-020-2169-0.
31. Zhang T, Wu Q, Zhang Z. Probable Pangolin Origin of SARS-CoV-2 Associated with the COVID-19 Outbreak. Curr Biol 2020; 30(7):1346–1351. DOI: 10.1016/j.cub.2020.03.022.
32. Denyer S, Yang L. China's Push to Export Traditional Medicine may doom the Magical Pangolin. The Washington Post. 22.07.2018. https://www.washingtonpost.com/world/asia_pacific/chinas-push-to-export-traditional-medicine-may-doom-the-magical-pangolin/2018/07/20/8d8c52d4-7ef1-11e8-a63f-7b5d2aba7ac5_story.html [last accessed on 21.04.2020].
33. Denyer S. Coronavirus Outbreak Underscores Potential Health risks in China's Wild Animal Trade. The Washington Post. 26.01.2020. https://www.washingtonpost.com/world/asia_pacific/coronavirus-outbreak-underscores-potential-health-risks-in-chinas-wild-animal-trade/2020/01/25/5f5353be-3f6f-11ea-971f-4ce4f94494b4_story.html [last accessed on 21.04.2020].
34. Cook R. A, Karesh W. B. Chapter 18-Emerging Diseases at the Interface of People, Domestic Animals and Wildlife. In: Miller R. E, Fowler M. Fowler's Zoo and Wild Animal Medicine. Saunders, Elsevier Inc.; 2012:136-146.
35. Hendrix C. S. Ensuring Global Food Security in the Time of COVID-19. (PIIE) *Pieterson Institute for International Economics.* 06.04.2020. https://www.piie.com/blogs/trade-and-investment-policy-watch/ensuring-global-food-security-time-covid-19 [last accessed on 21.04.2020].
36. FAO. Anticipating the Impacts of COVID-19 in Humanitarian and Food Crisis Contexts. *Food and Agricultural Organization of the United Nations*. 04.04.2020. http://www.fao.org/3/ca8464en/CA8464EN.pdf [last accessed on 21.04.2020.