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Article

Prevention and Mitigation of Zoonotic Disease Emergence Public Health Threats: Lessons in Tackling Ecological Issues

Thian-Hee Hee[1], Hui-Nee Au Yong[1], Yan-Ling Tan[2], Chee-Yin Yip[1], Foo Chuan-Chew Foo[1] and Abdelhak Senadjki[1]

[1]*Universiti Tunku Abdul Rahman, Perak, Malaysia.*

[2]*Universiti Teknologi MARA Cawangan Johor Kampus Segamat, Malaysia*

Correspondence should be addressed to:

Au Yong Hui Nee; auyonghn@utar.edu.my

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***Abstract*— Introduction: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a highly infectious and pathogenic coronavirus that appeared in the end of 2019. Coronaviruses are a family of virus that include the cold and SARS-CoV-2. The Coronavirus disease (COVID-19) pandemic triggered by SARS-CoV-2 has been categorised as a zoonotic disease, which is thought to originate from animals. COVID-19 can be serious, and has affected millions of deaths worldwide as well as long COVID-19. COVID-19 vaccination has been provided strong protection, contributed to lessening deaths and severe illness, and to reduce the spread. As humans diminish biodiversity by clearing forests and building more infrastructure, they are increasing the risk of disease pandemics. The COVID-19 pandemic has links to biodiversity loss and ecosystem health. Aim: The objective of this study is to investigate the effect of biodiversity loss towards the COVID-19 pandemic. The study investigates how biodiversity loss affects the COVID-19 cases. This study explores the relationship between the risks associated with biodiversity loss and COVID-19 pandemic. Methods: Using Pooled Ordinary Least Square (POLS) models while worldwide data collected of biodiversity loss and COVID-19 cases in 170 countries by obtained from IUCN Red List of Threatened Species and World Health Organisation respectively. Results: The study evaluated evidence that biodiversity loss affects the transmission of COVID-19. It was found that biodiversity loss is positively related to COVID-19 cases, the emergence of contagious disease. The total number of COVID-19 cases was found associated with biodiversity loss. The results suggest that the increased COVID-19 cases occurring in a country is linked to biodiversity loss that preventing the biodiversity loss could reduce the likelihood of future outbreaks. Deforestation can lead to a direct loss of wildlife habitat when animal species that live in the trees no longer have their habitat, with the removal of trees and other types of vegetation, cannot relocate. This habitat destruction leads to species' homes being uprooted. Habitat destruction is the leading cause of biodiversity loss. Findings of this study can help to suggest green space planning to maximize both environmental benefits health benefit. Conclusion: The COVID-19 virus may have developed from wildlife reservoirs connected to environmental disruption, was spread to humans. Deforestation and its changing landscapes have important implications for ecosystem functioning and biodiversity conservation. Increasing urbanisation and deforestation development have led to deforestation and associated biodiversity loss. Overall, in spite of some outstanding questions, current evidence implies that conserving intact ecosystems and their biodiversity should largely reduce the transmission of infectious diseases. This study highlight consequence that need to be mitigated. To avoid future pandemics and protect human health, governments should strengthen biodiversity conservation policies. Hence, more efforts to minimise deforestation and forest degradation must be part of the solution to the global crisis. Biodiversity and ecosystem conservation has to be an essential part of sustainable development strategies. There are many laws which aim to protect and safeguard the wildlife at protected areas for conservation. However, there**

are still many issues affecting the conservation efforts. In enhancing resilience, it will require policy change and government support if they are to be implemented. The link between human health and biodiversity could inspire green resolutions for humans to exist in a healthy balance with the environment heading to a long-term resilient future. Government policies must be focused on the causative factors to limit emerging outbreaks similar to COVID-19 in the future. Governments must minimize the threat of catastrophic disease outbreaks resulting from anthropogenic changes to the environment. The government should estimate the health impacts associated with their decisions to target their resources more effectively. Therefore, safeguarding biodiversity is not just on government or local communities, but this is a common heritage. Furthermore, the eco-health literacy should be further advancing under ecological public health model for sustaining the environment. Educating biodiversity should relate to new potentials for sustainable environment and progressing environmental and social justice, basic aspects of human health.

***Keywords*— Coronavirus Disease 2019 (COVID-19), Deforestation, Eco-System, Pandemic, Sustainable Development**

I. INTRODUCTION

Man disrupts the natural habitat of eco-system mainly because of economic consideration, resulting in the destruction of many animal habitats and thereby causing what is known as biodiversity loss. Does biodiversity loss have serious consequences on the health of mankind? As a result of this ecological disturbance, many animal viruses are forced to come out of the animal-virus eco system and pass on to man resulting in dreadful diseases, mostly respiratory disease like pneumonia example SARS and most recently, COVID-19 corona virus. All these viruses which can cause diseases has resulted in the loss of thousands of life, huge economic loss and untold suffering. The question arises is how to predict, mitigate or to prevent the outbreak of these virus-caused diseases.

According to Ministry of Natural Resources and Environment (MNRE) [8], biodiversity is the totality and diversity of living organisms on earth. It essentially consists of three components namely genes, species and ecosystems as the basic units [9]. In other worlds, biodiversity is referred to the variability among the three components. Specifically, species diversity resembles to the variety of different species; genetic diversity is referred to the gene's variety in animals, fungi, micro-organisms and plants, while ecosystem diversity corresponds to the different habitats such as coral reefs, hot and cold deserts, mountains, rivers, tropical forests, wetlands and others. However, natural world is decreasing at alarming rate while the species extinction rate is accelerating which, in turn, influence human lifestyle. Previous studies found the human (anthropogenic) drivers to be the most frequently cited contributing to the biodiversity loss. Identified anthropogenic drivers include habitat loss, degradation, fragmentation, over-exploitation, logging, fishing and hunting, pollution, introduction of exotic species and climate change [9, 10, 11, 12, 13].

There are a wide range of factors causing in the emergence of infectious disease or re-emergence of old infectious disease. "Emerging" infections is defined as "newly appeared in the populace or have existed but are fast rising in incidence or geographic range" [14, 15]. The instances of emerging diseases can be found in different locations are HIV (Human Immunodeficiency Virus) / AIDS (Acquired Immune Deficiency Syndrome), classic cholera in South America and Africa, cholera, Rift Valley fever, hantavirus pulmonary syndrome, Lyme disease, and haemolytic uremic syndrome [14]. In 2015, a group of scientist and public health expert from World Health Organisation (WHO) met in Geneva and listed top emerging diseases probably to trigger major epidemics. These include Crimean Congo haemorrhagic fever, Ebola virus disease and Marburg, Lassa fever, Middle East Respiratory Syndrome (MERS) and SARS coronavirus diseases, Nipah and Rift Valley fever. Reference [14] reported that specific factors contributing the emerging of disease can be identified through demographic, ecological or environmental factors that put public at intensified interaction with earlier unaware microorganism or its natural host or stimulate spreading. Reference [16] as cited in [15] noted that the most significant examples of emergence of infectious diseases were caused by human movement patterns and hence lead to new contacts across boundaries where the disease outbreak that were previously localized. Accordingly, [17] have identified that associating biodiversity loss can raise the incidence and distribution of infectious diseases in humans. Similarly, anthropogenic factors are frequently blamed for the emergence of new zoonoses from wildlife and transfer risk to humans [18, 19, 20, 21].

Recent work by [22] divided the biodiversity-disease linkages into dilution effect, amplification effect and idiosyncratic. Dilution effect occurs if rising in biodiversity leads to a lower risk of disease and subsequently biodiversity loss is expected to affect human and wildlife population negatively. Amplification effect reacts in the opposite way, where biodiversity loss will reduce the disease to wildlife and humans. The third one, idiosyncratic effect, will be referred to biodiversity loss have no effect on disease. Such context in the biodiversity loss-disease nexus has received a great deal of concern among previous studies [20, 21, 23, 24]. Nevertheless, the study on the degree of the biodiversity loss-disease emergence remains limited. The degree between two components can be generated if the shape of the biodiversity loss-disease link appears to be nonlinearity. In fact, a number of infectious disease spreads rapidly around the globe while the biodiversity loss appears to be growing over time. This shows that both processes occur concurrently. The situations are becoming more severe and unpredictable if one process to grow faster than, grow slower than, or grow at the same rate as another process. Therefore, the failure to explore the extent of the biodiversity loss-disease link will limit the efforts from different areas for projecting and reducing the impacts of future disease outbreak.

This paper aims to verify the correlation between animal loss and the emergence of contagious disease. Then it suggests effective measures to mitigate the chances of next

coronavirus pandemic outbreak and if the outbreak cannot be prevented, then how to reduce its damaging effect. However, this transmissible coronavirus issue is rather complex, which needs us to look at the problem in broader perspective leading us to the conclusion that this phenomenon is best to be investigated by introducing the concept of biodiversity and biodiversity loss. The latter in a narrow sense of the term always refers to habitat loss which is the main culprit for causing pandemics. Many environmentalists have given warning on this phenomenon.

II. LITERATURE REVIEW

Humans cause impacts to the physical environment in many aspects. Economic development is beneficial for a nation but the development poses as threats to the environment that the people may live in a developed nation however not in a healthy environment [1]. Consequently, social indicators are used to measure societal and individual wellbeing, dealing with issues e.g., health care [2].

Currently, the whole world is facing Coronavirus pandemic which is known as COVID-19 and is very infectious. This ferocious contagious disease can be said is the first such highly infectious disease strikes the world after more than 100 years. Currently, it has infected about 33 million people worldwide and has caused 1 million deaths. At the point of time, there is no cure yet for this pandemic virus. However, there are a couple of vaccines just approved for vaccination in the USA and a couple of western countries. The cause of this COVID-19 Pandemic is still unknown, but many theories have surfaced about its origin. Among all these theories, birds like bats harbour many of the same kinds of pathogens as humans and worse of all can span infectious agents to humans and other wildlife. It is the bats which is believed to have spread this coronavirus. It is a common knowledge that once the place of stay for living things are dislodged which we term as habitat loss, these living things will move to other places and this dislocation will force the pathogens moving out from these living things to find an easier host including human beings. These pathogens could be infectious to human health.

A. Biodiversity and Biodiversity Loss

Biodiversity means the variety of being on Planet. Biodiversity is vital to the well operating of ecosystems. However, habitat which essentially refers to places of staying by animals, birds or plant species is closely related to biodiversity. When these habitats are destroyed due mainly to climate change or deforestation, animals or birds would move to other habitats. This phenomenon is known as biodiversity loss which is defined as the decreasing number of a wide variety species of plant and animal existing in their natural environment mainly because of destruction of habitat.

This paper investigates mainly on biodiversity loss caused by deforestation by human activity. Deforestation is also known as overexploitation of the natural resources. It is recognized that biodiversity loss is mostly propelled by rapid population growth and unjustifiable consumption, and these are the leading bases of biodiversity loss which is now trending up to ten thousand times quicker than for millions of years before. And this has catastrophic effect on the health of human being.

Biodiversity loss is attributable to some reasons but by far the main wrongdoers are habitat devastation and over utilisation of species, led by exploding human numbers and unjustifiable utilisation. Thus, habitat loss can cause viruses that are contagious and dangerous to human health.

Therefore, the destruction of animal habitat is largely due to forest fire, flooding and human deforestation. However, among the three causes, human deforestation is the main culprit for causing contagious disease infecting human beings. Thus, we focus on this main factor “human deforestation”. With regard to climate change it will normally result in extreme weather change from very cold to very hot. This will in turn cause widespread intense forest fire like what is frequently happened in US and Australia. We focus on how and why habitat destruction, overexploitation of the environment, agriculture intensification and invasive species can cause the transmission of disease especially virus from animals to men.

B. Habitat Destruction

The world population is increasing rapidly and as a consequence larger population need more area. Harming human action prolongs to invade on ecological environments and thus damaging the environments of numerous species. As the population grows, urban centres and manufacturing zones are rising and integration into each other because of social cohesion and economic needs. This fragments the leftover habitat and giving secluded areas of plants and animals too tiny to endure.

C. Overexploitation

If the number of people grow rapidly, ever more things are needed. Humankind’s persistent depletion of resources. In addition, we are also setting massive burden on populations of wild species. Wildlife poaching and trafficking are still stage an enormous risk to many species. All these activities contribute to the destruction of habitat causing the transmission of virus like Coronavirus.

D. Agricultural Intensification

More population require more food, civilisation has grown agricultural systems which depend on artificial fertilisers, monocultures and pesticides. Monocultures are ever more receptive to disease whereas extensive pesticide use that damages insect populations indiscriminately. Furthermore, the rising stress on providing more food denotes an expanding ratio of farmland is cultivated extensively, with fewer off seasons which to recuperate. Presently, livestock

farming causes to additional climate discharges than the whole transportation sector and is the largest source of logging. Overflow from farms contaminates water bodies and triggers damaging algal blooms and the breakdown of fish stocks.

E. Invasive Species

Higher population mean extra movement. Human move across the globe has a very huge discharges footprint but it has also tolerated the proliferated of invasive species. As a result, we have left many weak ecosystems at risk, pressuring native species and weakening biodiversity.

Factors like loss of habitat, overexploitation of natural resources, agricultural intensification and invasive species contributed greatly in the transmission of contagious disease from animal species to human being simply because these disease needs easy hosts and animal struggling to get new habitat become difficult hosts for these contagious diseases.

It is a common knowledge that the main cause for the emergence of these contagious diseases is known to be climate change which causes massive forest fire and flooding, and the second one is deforestation by human being which resulted in loss of animal habitat which in turn causes biodiversity loss. Biodiversity loss has always been linked with the intensified surfacing of viral pathogens, e.g., SARS, Ebola and other bats' viruses [3, 4, 5]. This exposes populations to novel pathogen like the COVID-19. A typical example of how virus transmitted from animals to human is that contacts between human and Chimpanzee has headed to the outbreak of HIV [6, 7].

Our data set covered almost every country in this world. Study using secondary data to analyse this issue of the emergence of contagious disease as a result of biodiversity loss is very scare in the literature. We are confident that this study will more or less bridge this obvious literature gap. We work on a hypothesis that biodiversity loss is positively correlated with disease risk that is measurable and observable in the bio ecosystem. Moreover, we believe our results are robust providing useful information for policymakers throughout the world to make proper decision to make our biodiversity sustainable.

III. DATA, MODEL AND METHODOLOGY

To ascertain the relationship between the biodiversity loss and COVID-19, this research uses threatened species namely amphibian, bird, fish, mammal, mollusc, reptile, other invertebrate, plant, and total threatened species to proxy for biodiversity loss while total confirmed cases of COVID-19 to proxy for COVID-19. Moreover, the data of the threatened species data obtained from the IUCN Red List of Threatened Species in 2020 and the data of COVID-19 obtained from World Health Organisation (WHO). This study estimates one set of cross-sectional regressions for 170 countries in year 2020 and the basic model as follow:

$$DO_i = \theta_0 + \theta_1 BIOL_i + \mu_i \quad (1)$$

where DO and BIOL are the logarithm of the total confirmed cases of COVID-19 and biodiversity loss respectively in country i . θ_0 and θ_1 are the constant term and the regression coefficient, respectively, μ_i is residuals.

IV. RESULTS AND DISCUSSION

Using cross-sectional analysis, all the models were estimated in Table 1. Generally, this study collected 170 countries in year 2020 to estimate the impacts of biodiversity loss on COVID-19. Thus, this study collects the COVID-19 as the disease transmission.

Generally, the results of threatened species namely amphibian, bird, fish, mammal, mollusc, other invertebrate, plant, and total threatened species are statically significant for all the models in Table 1 except reptile. This indicates that, a 1% increase in mammal threatened, ceteris paribus, increases COVID-19 by about 0.672%. Meanwhile, the result of bird threatened exhibit a positive relationship with COVID-19. The parameter estimates reflect that, there are about 1.293% increases in COVID-19 with a 1% increase in bird threatened.

Using the amphibian threatened as the dependent variable, the relationship between amphibian threatened and COVID-19 is positive relationship. This suggests that, a 1% increase of amphibian threatened, increases 0.403% of COVID-19. As for fish threatened, results in Table 1 clearly provides that there is positive relationship between fish threatened and COVID-19. This shows that with a 1% increase in fish threatened and mollusc threatened, there are approximately 0.463% and 0.57% increase in COVID-19 respectively.

Other things being equal, a 1% increase in other invertebrate threatened and plant threatened increase COVID-19 by about 0.42% and 0.366% respectively. The result of plant threatened is among the most vulnerable. Based on the POLS model, the result of total threatened species is positive. This result implies that, a 1% increase in total threatened species, increase 0.739% in COVID-19.

To strengthen the aforementioned results, the robustness tests on the impact of biodiversity loss on COVID-19 are repeated with model developed upon POLS robust in Table 2. Next, Table 2 represents the cross-sectional analysis robust version. The results of Table 2 support the results in Table1. Moreover, threatened species such as amphibian, bird, fish, mammal, mollusc, other invertebrate, plant, and total threatened species increases COVID-19 for all the models except reptile. This can occur if there is a reduction in biodiversity due to urbanisation, large-scale farming or fishing, mining, or weaker forest law enforcement, especially in virgin forest areas. The results revealed that loss of biodiversity could contribute to cause COVID-19. Increasing human populations is the main factor. In other words, human habitation, interconnectedness and human resettlement were the contributing factors.

Table 1: The results of POLS for biodiversity loss on disease outbreak in 170 countries.

	Model 1 COVID-19	**Model 2** COVID-19	**Model 3** COVID-19	**Model 4** COVID-19	**Model 5** COVID-19	**Model 6** COVID-19	**Model 7** COVID-19	**Model 8** COVID-19	**Model 9** COVID-19
Mammal	0.672*** (3.28)								
Bird		1.293*** (5.82)							
Reptile			0.268 (1.57)						
Amphibian				0.403*** (3.19)					
Fish					0.463*** (2.74)				
Mollusc						0.570*** (4.14)			
Other Invertebrate							0.420*** (3.26)		
Plant								0.366*** (3.23)	
Total threatened species									0.739*** (4.02)
Cons	13.40*** (24.01)	11.38*** (17.05)	14.59*** (37.24)	14.60*** (57.98)	13.55*** (22.43)	14.21*** (48.98)	13.98*** (35.00)	13.85*** (31.73)	11.35*** (11.85)
R^2	0.0601	0.168	0.0144	0.0571	0.0427	0.0924	0.0596	0.0585	0.0876

Notes:*, **, *** denote significant at 10%, 5%, and 1% levels, respectively. *t* statistics in parentheses.

Table 2: The results of POLS robust for biodiversity loss on disease outbreak in 170 countries.

	Model 1 COVID-19	**Model 2** COVID-19	**Model 3** COVID-19	**Model 4** COVID-19	**Model 5** COVID-19	**Model 6** COVID-19	**Model 7** COVID-19	**Model 8** COVID-19	**Model 9** COVID-19
Mammal	0.672*** (2.87)								
Bird		1.293*** (5.71)							
Reptile			0.268 (1.58)						
Amphibian				0.403*** (3.43)					
Fish					0.463*** (3.20)				
Mollusc						0.570*** (3.83)			
Other Invertebrate							0.420*** (3.21)		
Plant								0.366*** (2.94)	
Total threatened species									0.739*** (4.18)
Cons	13.40*** (21.30)	11.38*** (16.66)	14.59*** (39.92)	14.60*** (58.67)	13.55*** (27.79)	14.21*** (48.60)	13.98*** (44.65)	13.85*** (29.33)	11.35*** (12.76)
R^2	0.0601	0.168	0.0144	0.0571	0.0427	0.0924	0.0596	0.0585	0.0876

Notes:*, **, *** denote significant at 10%, 5%, and 1% levels, respectively. *t* statistics in parentheses.

IV. CONCLUSIONS

The COVID-19 pandemic is an alert on future socio-economic disturbances that the humankind may face with loss of biodiversity and public health emergencies. Loss of biodiversity hence ecosystem destabilisation was found the key driving causes the infectious disease emergencies. Host susceptibility, is at the peak of the pinnacle since parameters depended on environment changes, socio-behavioural changes and consumption habits, etc.

The lessons learned from this crisis can be used to extend opportunities for handling gaps in community resilience and health imperatives through planning. It highlights the requirement for putting more emphasis on legislation, enforcement as well as public health facilities to reduce vulnerabilities and improve resilience to external shocks from infectious disease outbreaks. The researcher recommends that countries must go beyond the 'control of the risk' approach with implementation of strategies to cope with the crisis. The results provide a guide for authorities to identify the antecedents that are resulting in infectious disease outbreaks. It should also be helpful in enhancing their programs to preserve the environment to minimize the outbreak of infectious disease in the future.

A. Public Policy Implications

The COVID-19 pandemic increased people's awareness that a virus can put on humankind and of the uncertainty to the human condition. Loss of biodiversity and ecosystem destabilization are due to human over-exploitation of nature and natural resources, disrupting the ecosystem balance. Furthermore, a globally synchronised approach to ecological sustainability is needed for improving the human, societal, and ecological health.

Sustainable forest management systems and environmental regulations are hard to enforce, so are practical issues associated with large-scale farming or fishing and stopping the wildlife trade. Careful handling of wildlife and their habitats along with regulation of wildlife trade is needed to prevent not only loss of biodiversity as well as in ensuring future human existence. In this context, conservationists, NGOs and government agencies should work on preserving the wildlife in large scale. A good idea is to build buffer zones.

This is because the buffer zones permit species to leave the preserve without immediate, catastrophic repercussions, such as predation or lack of food or water. Another way to improve the biodiversity is by restoration. The loss of variety in an ecosystem may result from the elimination of a keys species. Re-inhabiting the key species would have a positive impact on the health of a whole ecosystem. It makes sense to try to re-inhabit key species to their original habitat if they were removed and to safeguard these species wherever feasible.

In addition, government should relook at the national zoos' core purposes from collection and display spaces to conservation-focused institutions. Zoos may contribute to conservation efforts through educational programs. Zoos should inspire visitors to do conservation-related acts.

Adaptive conservation management should be applied, by monitoring and adjusting biodiversity populations. interventionist, NGOs, and government agencies should apply tactics and procedures fitted for fragile, threatened, and endangered species. The demand for elephants' horn has led to a dramatic reduction in the population of elephants in Malaysia. Therefore, conservationists should establish and properly maintain multiple-use biological reserves, national parks, nature reserves and protected areas. Reserves would save wildlife and its natural environments, therefore preventing certain species such as elephants from going extinct. The ecological integrity of ecosystems is becoming an increasingly central emphasis in the establishment of biological reserves.

All these preventative measures may not work better if it were not backed by strong political motives. The protection of endangered species is directly impacted by the ban on the wildlife species trade. If there are strong environmental protection policies, then a remarkable recovery of the wild species would be significant and successful. The priorities for public investments are the support for green infrastructure and development of sustainable cities. Governments need to interfere and invest in green, health and social infrastructures in respond to infectious disease outbreaks in the future. COVID-19 has shown the humankind how interconnected with the nature globally and the intersections between modern challenges, and the way human behaviour and environmental change that triggering worldwide crises.

The involvement of production of large-scale farming is probable to be crucial to incentivising forest clearing behaviour. These behaviours could be motivated by weaken enforcer capacity against illegal activities.

The natural ecosystems need to be sustainably managed when human society interacts with the nature to satisfy demand for economic development [25]. Therefore, the society expects changes in long-term toward improved sustainability [26]. This suggests a comprehensive agenda for future research into these very important policy issues.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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