An Analysis of the Ecological Framework of Modelling the Geographical Transmission of Disease and the Study of the Influence of Ecosystem and Disease on Each Other

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Abstract

The chapter explores the complex relationships between ecosystems, humans, and disease, particularly according to the ecological framework, along with the geographical transmission of disease. However, the chapter also provides a general overview related to the effect of the ecosystem and disease on each other, as an alteration in an ecosystem can directly or indirectly influence the spread of disease, particularly where harmful microorganisms survive. In contrast, disease can also affect an ecosystem by changing the host population and the factors associated with this. This review also covers a brief overview of the most important approach known as the One Health approach, which mainly recognizes the connection among humans, animals, and even the environment, further helping in making strategies to prevent or control disease epidemics or outbreaks. It is essential to understand the phenomenon of the effect of disease and the ecosystem on each other to control the spread of the disease.

Keywords: Disease Transmission, Ecosystem and Disease Interactions, Ecology, Geographical transmission, Infectious Diseases, One Health Approach.

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Introduction

The recent emergence of infectious diseases has great impact on disease transmission in the ecosystem (Pike et al., 2014; Fan et al., 2017). A total of 60% of the emerging infectious diseases in humans caused by pathogenic parasites are of zoonotic origin (Plowright et al., 2017). An ecological framework of disease transmission emphasizes the study of the relationship between host, pathogen, and their environment on each other and the underlying mechanism, particularly in terms of disease transmission. This phenomenon studies the factors responsible for the uncontrolled spread of the disease, host activities making it vulnerable to get disease, environmental factors, and disease prevention. Understanding this is important because of the potential spread of the disease that is not only confined to humans but also to animals (Johnson et al., 2019). In a disease system, there exists a minimum of two interacting species, such as the host and parasite. The complexity of disease transmission varies depending on the host factors. As we know, parasites infect a large host range, so they need a specific transmission source for their spread, either in the form of a reservoir host or a vector. Here, we consider parasite disease-causing pathogens broadly classified as microparasites, such as bacteria, viruses, fungi, and protozoa, and macroparasites, such as flatworms and nematodes, etc. (Luis et al., 2015; Olival et al., 2017). Disease transmission has adverse impacts on public health, as a number of environmental and host variables are responsible for the spread of infectious diseases. It is significant to develop novel and effective strategies to tackle the disease transmission in order to understand the ecological framework of disease transmission (Van Seventer & Hochberg, 2016). Keeping in view the concept of ecological framework, the aim of this chapter is to understand the relationship between ecosystem, disease, and their impacts on each other.

Ecological Framework for Disease Transmission

An ecological framework of disease transmission evaluates and determines the interactions between environmental factors and host populations, which are mainly involved in the spread of various infectious diseases (Arthur et al., 2017). Some of the environmental variables and pathogen traits also have a huge impact on the spread of disease globally. Changes in climate and weather also impact the habitat of the host and vector. However, pathogen characteristics play an important role in the transmission and emergence of disease within the host species

(Engering et al., 2013; Nichols et al., 2018). The number of people may also become a cause of spreading the disease, particularly in crowded places. The common example is respiratory diseases, which commonly spread in crowded places (Ferkol & Schraufnagel, 2014; Ramon-Torrell, 2023). Moreover, the virulency of a harmful microorganism, along with the way of transmission and effect on the host, may also increase the chance of infections in many individuals (Hakansson et al., 2018). The microorganisms that can be easily transmitted through the air can be transmitted more quickly than other diseases, which may be transmitted due to other reasons (Meena et al., 2019).

Thus, it is very crucial to know how diseases are transmitted, such as via respiratory droplets, direct contact, by food and water, or by vectors, etc., to control the transmission of infections (Straif-Bourgeois et al., 2023). Other factors may include poverty, compromised immune system, overpopulation, and restricted access to health care facilities, etc. (Uzoka et al., 2021).

Geographical Transmission of Disease

Geographical transmission of disease describes how an infectious disease can spread across different regions. The main and important factors which mainly involved in the geographical transmission of diseases include human movement, such as travel and trade, and environmental conditions. This tells how disease clusters move rapidly and spread due to travel and migration in humans (Ma et al., 2022). Some of the diseases that exhibit geographical transmission include SARS, measles, and influenza etc. The spread of SARS exhibits how a disease can move rapidly between interconnected regions. However, travelers can acquire some other infections, like malaria and dengue, particularly when traveling to tropical regions (Smith, 2010).

However, to evaluate the geographical transmission of diseases, spatial analysis, disease mapping, and predictive modeling play a vital role. Spatial analysis can help in identifying areas with a high risk of transmission of disease. While disease mapping can help in integrating public health interventions and in predicting outbreaks. On the other hand, statistical models and various machine learning models can detect disease transmission, particularly based on environmental factors (Cheng et al., 2024).

Geographical Transmission of Infectious Diseases

Geographical transmission of infectious disease refers to how they spread across various locations, mainly influenced by climate and geography. The examples include vector-borne diseases, water-borne diseases, soil-borne diseases, foodborne diseases, diseases associated with animal reservoirs known as zoonotic diseases, and diseases transmitted by direct contact (Findlater & Bogoch, II, 2018). Various infectious diseases distributed all over the world are shown in Figure 1.

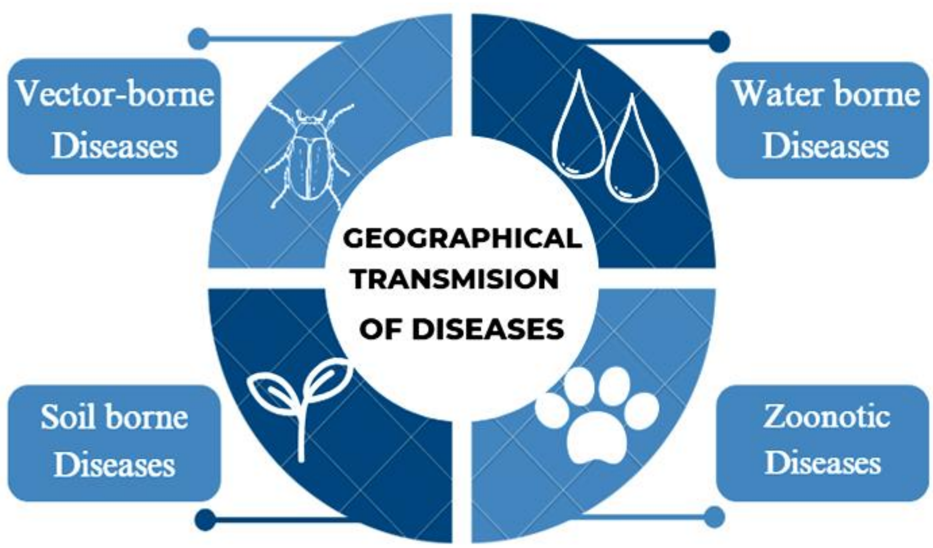

Fig. 1: Global prevalence of various infectious diseases

Vector-borne Diseases

Human activities provoke the transmission of many vector-borne diseases. A number of vector-borne diseases like leishmaniasis and Chagas disease are causing critical public health havocs. The mechanism of vector-borne diseases involves both biotic and abiotic components of the ecosystem, which provide habitat to the vector organism (LaDeau et al., 2015). A vast majority of hematophagous arthropod diseases are vector borne transmitted via blood feeding, such as viral diseases (West Nile virus and Dengue virus), bacterial (Lyme disease and plague disease), protozoan (trypanosomiasis and malaria), and nematodes (filariasis) (Giraudeau et al., 2014). Human behavior, cultural practices, and socio-economic dynamics stimulate the biotic and abiotic factors of the ecosystem and interaction among species present in the ecosystem, contributing to the ecological disease system (Levy et al., 2014). Arthropod vectors, small ectothermic organisms, depend on climate change, temperature alterations, and human behaviour for their proliferation and survival, and they quickly respond to the environmental changes (Paaijmans et al., 2013). Female *Anopheles* mosquito acts as a mechanical vector for the transmission of the malarial plasmodium to the human blood (Caminade et al., 2014; Agyekum et al., 2021). Dengue virus is transmitted by female *Aedes aegypti* (Ebi & Nealon, 2016; Baker et al., 2022).

Waterborne Diseases

The spread of diseases due to contaminated water supply is commonly known as waterborne illnesses, and alterations in climate and human activities have a significant impact on it. (Nwabor et al., 2016; Manetu & Karanja, 2021). Some of the common examples include typhoid fever, giardiasis, cholera, and Hepatitis A or E, which are mainly common in areas with poor and contaminated water supply (Nichols et al., 2018; Pal et al., 2018).

Among these, Typhoid is a bacterial infection that is commonly transmitted due to contaminated food or water (Brockett et al., 2020; Bashir et al., 2024). In addition, like typhoid fever, cholera is also a bacterial infection, commonly spread through the ingestion of water or food contaminated by feces (Kabwama et al., 2017; Mudaua et al., 2017). In addition to this, amoebiasis is mainly spread by the fecal-oral route and drinking fresh water mainly contaminated with the parasite known as *Entamoeba histolytica*, causing amoebic dysentery (Singh & Galhotra, 2014; Huang et al., 2025). Unlike cholera and typhoid, giardiasis is a parasitic infection, but it is also spread through to fecal-oral route and contaminated water (Minetti et al., 2016; Omarova et al., 2018). Moreover, hepatitis A and E are viral infections and are also associated with transmission through the fecal-oral route and contaminated water (Hofmeister et al., 2019). All these discussed waterborne diseases are commonly associated with areas with a poor sanitary environment (Hofmeister et al., 2019).

Soil-borne Diseases

Like vector-borne and waterborne diseases, the soil-borne diseases can also be spread due to numerous environmental variables, as well as a result of various human activities (Caminade et al., 2019). When soil becomes contaminated due to various harmful microorganisms, it can easily spread diseases from one location to another, which can then ultimately impact the life of plants and lead to infectious diseases in both humans and animals (Ashraf et al., 2014; Katan, 2017). These infections are mainly common in some of the regions, including South Asia, Africa, and South America (Silver et al., 2018). Moreover, some of the bacterial infections, including tetanus, botulinum, and anthrax, can be transmitted through soil-contaminated wounds, further leading to the risk of soil-related diseases (Nieder et al., 2018). Notably, some common bacteria, including *Salmonella enterica* and *Escherichia coli,* can also be transmitted via soil, ultimately leading to gastrointestinal infections (Ongeng et al., 2015). These types of infections can occur when crops become contaminated by irrigating with polluted water (Black et al., 2021).

Emerging Infectious Diseases

Some of the emerging infectious diseases, which are mainly based on their geographical transmission, include H1N1 flu, SARS-CoV-2, and HIV etc. The H1N1 flu virus mainly spreads during human travel and migration and affects individuals of all age groups (Findlater & I. I. Bogoch, 2018). While the transmission of human immunodeficiency virus is particularly common in Africa and can be transmitted more easily where there are travel routes, indicating that human mobility can give space to the transmission of a disease (Eshraghian et al., 2020). Moreover, severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) is a severe viral infection, and its origin is the animal reservoir, indicating how a disease can come from animals to humans. The emergence of such zoonotic diseases can be due to various reasons, including deforestation and violations of nature (De Sadeleer & Godfroid, 2020; Zhang et al., 2025). The SARS-CoV-2 first originated in Wuhan, China, in December 2019 and spread throughout the world immediately via aerosol spread, which claimed millions of lives all over the world (Hashemian et al., 2025; Rustagi et al., 2025).

Influence of Ecosystem and Disease on Each Other

The Ecosystem and disease have a complex and significant relationship with each other, as shown in Tables 1 and 2. Thus, any changes in the ecosystem can directly and indirectly influence the spread of disease, particularly in the environment where vectors and harmful microorganisms survive. In contrast, disease can affect the ecosystem by affecting host populations and their interactions (Paseka et al., 2020).

Table 1: Factors involved in the ecosystem influencing the disease

Sr. No.	Ecosystem influence on disease	Description	References
1	Habitat Alteration	A change in deforestation and habitat loss can increase contact between humans, wild animals, and vectors, ultimately leading to transmission of zoonotic diseases.	(Dubey et al., 2023)
2	Biodiversity	Reduced biodiversity can increase the risk of disease by focusing hosts and decreasing the diversity of defenses.	(Jactel et al., 2017)
3	Climate change	Climate change affects the vector population and the life of the pathogen, ultimately leading to a change in disease rate and geographical distribution.	(Uwishema et al., 2023)
4	Water quality	Management of water resources and pollution can affect the quality of water, ultimately leading to the spread of waterborne diseases.	(Ntajal et al., 2020)

Table 2: Factors involved in the disease influencing the ecosystem

Sr. No.	Disease influence on the ecosystem	Description	References
1	Host Population Dynamics	Disease can affect host populations, ultimately leading to a decline in population or a change in species composition.	(Cable et al., 2017)
2	Disturbance Regimes	Disease can alter disturbance in regimes, including insect or wildfire outbreaks, by affecting the host susceptibility and population.	(Fischhoff et al., 2020)
3	Ecosystem Services	Disease can affect the ecosystem services, including pollination and water filtration, etc, by impacting the health of species.	(Paseka et al., 2020)
4	Evolutionary changes	Disease can cause evolutionary changes in hosts and pathogens, ultimately leading to adaptations and the emergence of diseases.	(Rogalski et al., 2017)

Studying the Influence

There should be a collaboration among various fields, such as ecology, epidemiology, and other scientific fields, to study the effect of ecosystems and diseases on each other properly and effectively, along with understanding the relationship between human activities with disease. Ecology is a field that mainly focuses on the relationship between organisms and their environment, while epidemiology studies the prevalence and cause of diseases. Therefore, to understand the relationship between the ecosystem and disease, collaboration among various interdisciplinary health professionals, such as epidemiologists, ecologists, and public health professionals, is needed and is crucial (Galway et al., 2016; Arthur et al., 2017).

One Health Approach

One health agenda focuses on the human, environment, and animal health under one platform (Abdullah & Shaikh, 2025; Ginnan et al., 2025). It is an important approach mainly in understanding disease transmission concerning human, animal, and environmental health, which is further described in Table 3. Thus, by adopting this holistic approach, various strategies can be developed to prevent and tackle disease outbreaks, ultimately promoting human, animal as well and environmental health (Mackenzie & Jeggo, 2019).

Table 3: One Health Approach in understanding disease transmission

Sr. No.	One Health Approach	Description	References
1	Human Health	The One Health approach recognizes the impact of human activities on environmental health, such as the impact of urbanization on the population	(Duval et al., 2023)
2	Animal Health	On Health approach recognizes the role of animals as reservoirs and the impact of animal health on the transmission of human diseases.	(Mukhtar et al., 2023)
3	Environmental Health	One health approach helps to understand the impact of ecosystem changes on disease transmission, such as the effect of deforestation on vector-borne diseases.	(Burkett-Cadena & Vittor, 2018)

Future Perspectives

The ecosystem and disease interactions have gained remarkable attention in recent decades. Therefore, the main and important advancements which need to be focused on are using some advanced technologies alone or in collaboration with others, including machine learning and genomics etc. These advancements can enhance disease prediction or control, as these tools can be beneficial in predicting outbreaks and informing public health interventions. Thus, by developing innovative and advanced predictive models and tools, the areas with a high risk of disease transmission can be identified properly. These models can combine environmental and human factors in predicting outbreaks, further leading to targeted interventions. It is crucial to focus on exploring the direct or indirect influence of climate change on disease transmission so, various beneficial strategies can be developed to minimize the effects. Moreover, advancement in international cooperation is necessary to respond to emerging diseases efficiently. Our global health security needs proper and efficient surveillance systems along with effective coordination to tackle disease outbreaks. In addition, community engagement is also very important in terms of disease prevention and control to improve health status. Some of the important initiatives, if taken by a majority of the population then it can improve disease along with change in behavior, which can further support interventions, particularly related to public health. So, only by developing and also implementing ecosystem-related interventions, the risk of disease transmission can be minimized, ultimately promoting human and animal health along with positive change in environmental status. These type of strategies restores natural ecosystems, and ultimately promote biodiversity. In short, exploring the effect of ecosystem changes on disease transmission, developing ecosystem-related interventions, increasing predictive modeling, enhancing interdisciplinary cooperation and community participation, along with research findings, can all help in the future to manage disease and ecosystem interactions.

Overall, keeping in view the challenges, the understanding related to ecosystem and disease interactions, we can develop effective strategies to prevent and tackle disease outbreaks, which will promote human health and environmental status in the future.

Conclusion

Overall, the ecological framework of disease transmission is a conception which requires an approach to understand the relationship between ecosystems and disease. Thus, it is very important and necessary to understand the ecological framework of disease transmission along with the impact of disease and ecosystem on each other, as it can be beneficial in developing functional strategies that can further prevent and control disease outbreaks. Furthermore, studying the impact of disease and ecosystem on each other requires cooperation and communication among epidemiologists, ecologists, and even public health experts. However, further research is required to discover the interactions between the ecosystems and diseases. The future perspective underlines the need for a One Health approach to emphasize the connection between humans, animals, and the environment to control disease transmission.

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