ANALYSIS OF URBAN FOREST DEGRADATION AND VULNERABILITY TO ZOONOTIC DISEASE OUTBREAK IN MINNA, NIGER STATE, NIGERIA

By

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ABSTRACT

Degradation of urban forests is a direct form of land degradation leading to human-wild animal interactions and thus increasing the risk of zoonotic disease emergence. As humans degrade urban forest structure and composition, there is likelihood for increasing the risk of zoonotic disease such as COVID-19. This study is aimed at examining the effect of urban forest degradation on vulnerability to declining ecosystem services and consequent zoonotic disease outbreak and incidence in Minna town. The study employed field survey method based on quantitative analysis of 8 indicators of urban forest (structure and composition) degradation; 18 indicators of ecosystem services degradation and 5 indicators of vulnerability to pandemic incidence. Relative Importance Index (RII) and Ecological Risk Index (ERI) were used to analyze the data collected. Findings from the study revealed that virtually all the parameters of structure and composition of urban forest have undergone significant degradation. It was also found that ecosystem services have declined considerably over the 30 years covered. Consequent upon the current status of urban forest ecosystem degradation, ERI was generally found to be high (ranging from 0.383 to 0.764.). The study thus conclude that urban environment in Minna is conducive to host potentially dangerous conditions and pathogens that can trigger or escalate some poor human health conditions. This study provides a structured approach to exploring the interconnectedness between urban forest degradation and increased vulnerability to disease outbreaks. The study hereby recommends urban forest restoration by planting and maintenance of trees in the neighborhoods by households, establishing more green corridors and protecting existing green paces by urban control board.

Keywords: Degradation, Ecosystem services, Urban forest, Vulnerability, Zoonotic disease

INTRODUCTION

Globally, the current rate of urbanization is quite alarming, as urban areas are projected to accommodate 68% of the world's population by 2050 (United Nations, 2018). By 2050, three billion additional people will live in cities; meanwhile, urbanization is often susceptible to environmental problems. Ecological systems provide humans with ecosystem services essential for good health and survival. Regrettably, ecosystem degradation has increased the risks and threats to human health (Millenium Ecosystem Assessment [MEA], 2005; Singhal et al., 2024) yet, there is limited empirical studies on causal pathways between urban forest degradation and pandemic vulnerability (Kang et al., 2025). Most efforts to stem the tide of pandemics tend to

focus on vaccine development, early diagnosis and containment, which is akin to treating the symptoms without addressing the underlying cause(s). In recent years, there has been a growing interest by the scientific community on the potential links between the degradation of an ecological system and its impacts on human health (Fanelli et al., 2025).

The urban forest is defined as all the trees in the urban areas including individual trees and shrubs, parks and forests in public and private spaces, along linear routes and waterways and in amenity areas. It contributes to green infrastructure and the wider urban ecosystem (Urban Forestry and Woodlands Advisory Committees Network [UFWACN], 2016). The urban forest consists of all of the trees growing on public and private lands, including trees in the downtown, old and new neighborhoods, commercial and institutional lands, city parks, and natural areas. Urban forests play a crucial role in improving the environmental health quality of cities and urban dwellers (Roy et al., 2012; Shwartz et al., 2014).

Urban forest degradation and vulnerability to zoonotic diseases are directly linked to Sustainable Development Goals (SDG) 3 - Good Health and Well-being - as healthy forests act as buffers, reducing human-wild animal interactions and thus lowering the risk of zoonotic disease emergence (the source of many pandemics). SDG 15 (Life on Land) focuses on protecting, restoring, and promoting sustainable use of terrestrial ecosystems and halting biodiversity loss. It considers healthy urban forests potentials to reduce public health risks by improving air quality, moderating urban heat islands, and providing spaces for physical activity and mental decompression (Nova et al., 2022), which became crucial during the COVID-19 pandemic. Degradation of these spaces leads to poorer health outcomes and heightened vulnerability during health crises (Singhal et al., 2024). SDG 11 (Sustainable Cities and Communities) aims to make cities inclusive, safe, resilient, and sustainable. Urban forest green spaces are critical infrastructure for urban resilience, managing stormwater, and improving livability. Well-planned urban forestry is a nature-based solution to urban challenges, including pandemic resilience (Fanelli et al., 2025).

Urban forests, and the ecosystem services they provide, are necessary for healthy living conditions. Quantifying the status and the vulnerability to degradation of this resource are essential for maintaining a consistent and equitable supply of these ecosystem services. The integral parts of broader landscapes of urban forests trees contribute to the stability and vitality of ecosystems and to meeting societal needs. However, the devastating effects of the pandemic on human health, the economy and society are undeniable (Jones et al., 2008; Kang et al., 2025).

Zoonotic diseases are diseases that pass from an animal to a human. Many ecologists have long suspected this, because, as some species are going extinct, those that tend to survive and thrive, for instance, rats and bats, are more likely to host potentially dangerous pathogens that can make the jump to humans (Fanelli et al., 2025). Climate change, loss of biodiversity and habitat fragmentation heighten risks of zoonotic disease emergence and transmission (Lindner et al., 2009; El-Sayed et al., 2020; Nova et al., 2022) Studies have long been delving into relationships between biodiversity, land use and emerging infectious diseases (Jones et al, 2008; Nova et al., 2022). However, the analysis of evidence that connects trends in human development and biodiversity loss to disease outbreaks, stops short of projecting where new disease outbreaks are likely to occur (Tollefson, 2020). As the world contends with the pandemics, efforts to map risks in communities around the globe and to project where diseases are most likely to emerge are crucial.

Urban forest degradation reduces ecosystem services, limiting access to restorative environments and increasing urban stress (Obateru et al., 2024; Obateru et al., 2025). The urban forest structure,

composition and function in Minna town is not insulated from alteration and degradation occasioned by increasing rate of urbanization in the last three decades; which could have created conditions that favors emergence of pandemic diseases such as COVID-19. This study is aimed at examining the effect of urban forest degradation on vulnerability to declining ecosystem services and consequent zoonotic disease outbreak and incidence in Minna town. The specific objectives were to evaluate the current status of urban tree structure and composition; examine the condition of urban forest ecosystem services; and assess the indicators of vulnerability to zoonotic diseases in Minna town.

This study is based on the conceptual framework of social–ecological systems which depicts relationships between Society, Ecosystem Services, and Human health (See Figure 1). The study of social–ecological systems often entail direct focus on linkages between social and ecological processes, the supply of natural resources and ecosystem services, and complex environmental problems (Grove, 2009; Binder et al., 2013). There are functional and complex relationships between ecological systems, their services, human society, and infectious diseases. The primary drivers of ecosystem changes are linked to population growth and economic development. These changes trigger several ecological mechanisms that can often increase the risk of infectious disease transmission or can change conditions of vulnerability, such as malnutrition, stress and trauma (in floods and storms, for example), immunosuppression, and respiratory ailments associated with poor air quality.

There is a wide spectrum of human disturbances to ecosystems and their services that may change disease risk via biological mechanisms. Most emerging diseases are driven by human activities that modify the environment or otherwise spread pathogens into new ecological niches (Taylor et al., 2001). These anthropogenic drivers of ecosystem disturbance can lead to specific changes in ecosystems that may or may not lead to disease emergence via mechanisms that are more directly relevant to life cycles or transmission of infectious diseases. There is concern that the extent of ecosystem changes in recent decades and the multiple ways in which habitats and biodiversity are being altered are increasing the odds that infectious diseases will be affected at some level. The specific biological mechanisms altering disease incidence, emergence, or reemergence are described here and, by way of illustration, disease case studies in this chapter are organized according to these biological mechanisms.

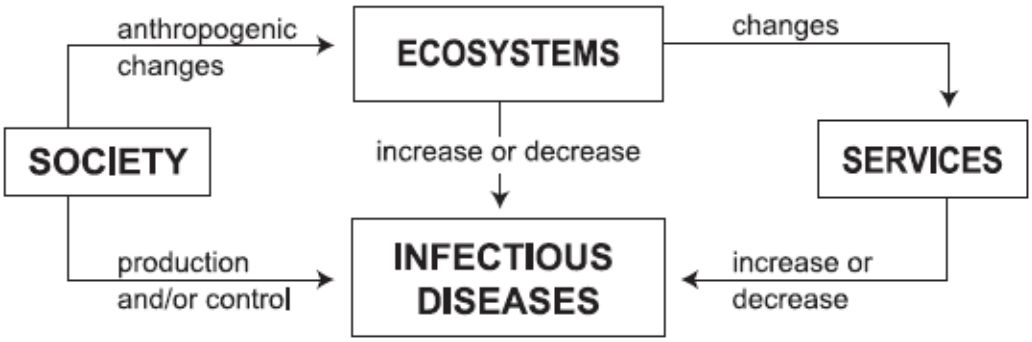

Fig. 1: Relationships between Society, Ecosystem Services, and Human Infectious Diseases
Source: Jonathan et al., (2005).

Intact ecosystems maintain a diversity of species in equilibrium and can often provide a disease-regulating effect if any of these species are either directly or indirectly involved in the life cycle of an infectious disease and occupy an ecological niche that prevents the invasion of a species involved in infectious disease transmission or maintenance. Disease agents with much of their life cycle occurring external to the human host, such as water- and vector-borne diseases, are subjected to environmental conditions, and it is these diseases for which most linkages to ecosystem conditions have been found (Patz et al., 2000).

THE STUDY AREA

Minna being the capital of Niger state is found in the North central region of Nigeria. It is located on Latitudes 9°35′ North to 9°40′ North and Longitudes 6°30′ East to 6°35′ East (Figure. 2). It occupies a land area of about 6,784 km^2. The study area has a sub-humid tropical continental climate characterized by alternating wet and dry season; coded as 'Aw' by Koppen's classification. The mean annual rainfall is about 1,284 mm. The wet season begins in May and ends in October, while the months of November to April are dry season. The mean annual temperature is about 32^{o}C. Physiographically, Minna has a gently undulating high plains developed on basement complex rocks made up of granites, migmatites, gneisses and schists. Inselbergs of "Older Granites" and low hills of schists rise conspicuously above the plains. Beneath the plains, bedrock is deeply weathered and constitutes the major soil parent material (saprolites) (Ojanuga, 2006). The study area is found in Southern guinea savanna, characterized by typical woodland of deciduous plant communities with common trees species such as *Khaya spp., Parkia biglobosa, Delonix regia, Eucalyptus spp., Azadirachta indica and Gmelina arborea*.

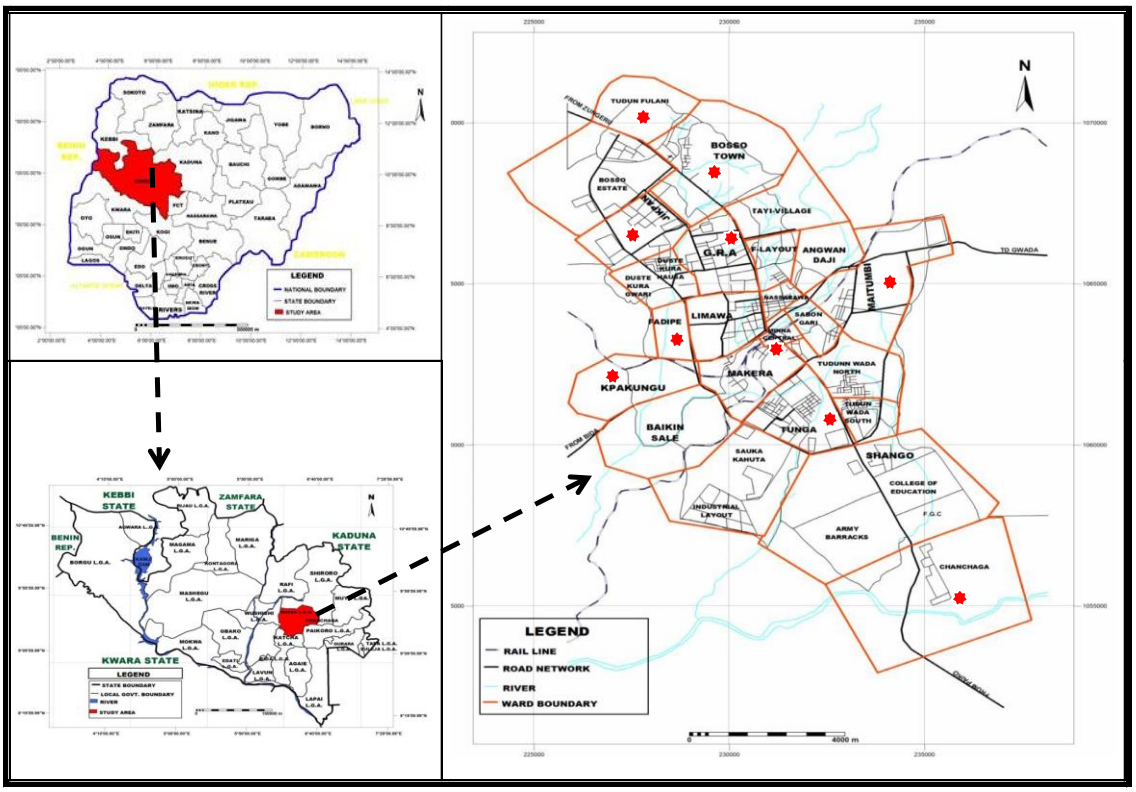

Figure 2: Geographical location of study area
Source: Adapted from the administrative map of Niger State (2018)

MATERIALS AND METHODS

The study commenced with a reconnaissance survey in order to familiarise with the area and to plan for field data collection. The research made use of questionnaire survey and quantitative technique of data analysis. Total Population of Minna, (based on 2006 census) of 348,788 was projected to 2021 at an average growth rate of 3.2% giving a total population of 524, 097, and the sample size was determined using the Yamane (1967) formula as Equation 1.

$$n = \frac{N}{1+N\,(e)^2} \qquad \text{Equation 1}$$

Where:

n = Sample Size; N = Population size; 1 = Constant e = The level of precision

A 95% confidence level and P = 0.5 yielded a sample size of 397. Due to lack of reliable population data of the neighborhood/streets in Minna, equal number of 40 copies of questionnaire were administered to randomly selected household heads in all the ten neighbourhoods/streets including Bosso, Chanchaga, Fadikpe, G.R.A., Jikpan, Kpakungu, Maitumbi, Minna Central, Tunga, and Tudun Fulani.

Relative Importance Index (RII) was used to assess the perceived condition, status, severity and frequency of urban forest degradation and impact on ecosystem services; based on weighted five point Likert scale as follows: *Severity* (Very High=5, High=4, Moderate=3, Low=2, Very Low=1) *Frequency* (Very High (1-5 Years)=5 High (6-10 years)=4 Moderate (11-15 Years)=3 Low (16-20 Years)=2 Very Low (21-25 Years)=1). RII sum of weight is presented in the formula as Equation 2.

$$RII = \frac{\sum(W_i \times n_i)}{A \times N} \qquad \text{Equation 2}$$

Where:

W_i = weight of assigned to a specific response choice
n_i = total count for a specific response choice
A = highest weight (in this case, 5)
N = Total number of respondents

Assessment of the degree of risk took into account the severity of a given stressor and the degree of alteration or potential and the frequency with which a given stressor causes alteration or disturbance in functional aspects. Based on this theoretical framework, Mattson & Angermeier (2007) proposed the Ecological Risk Index (ERI), which is used to assess the stress to which a particular ecosystem or area is subjected. Its mathematical representation can be expressed as in Equation 3:

$$ERI_{(i)} = F_{(i)} \times S_{(i)} \qquad \text{Equation 3}$$

Where:

F (i) = frequency of stressor 'i' considered.
S (i) = severity of stressor 'i' considered.

The classification of level of ecological risks is as presented in Table 1.

Table 1: Classification of Level of Ecological Risks

ERI score	Level
› 0.76	Very high
0.67 – 0.75	High
0.45 – 0.66	Moderate
0.23 – 0.44	Low
‹ 0.22	Very Low

RESULTS AND DISCUSSION

Socio-Demographic Attributes of Respondents

The analysis of socio-demographic attributes of the respondents (see Table 2) indicates that majority of the respondents, about 70% were males. The dominance of the male respondents can be attributed to the socio-cultural norms and values of the communities in Minna where headship of households is an exclusive preserve of the males, except in some few cases where the husband is deceased.

Table 2 Socio-Demographic Characteristics of Respondents

Variable & Categories	Frequency	Percentage
Sex		
Male	279	69.75
Female	121	30.25
Age (Years)		
< 30	84	21
30 - 40	94	23.5
41 – 50	143	35.75
> 50	79	19.75
Level of Formal Education		
None	0	0
Primary	33	8.25
Secondary	164	41
Tertiary	203	50.75
Experience in Urban tree Mgt. (Years)		
5 - 10	118	29.5
11 - 20	143	35.75
21 - 30	108	27
>30	31	7.75

As indicated in Table 2, most of the respondents were found to be over 40 years old; which implies they could be conversant about changes in the urban trees structure and composition over the last 30 years. Virtually all of the respondents were literate; with an overwhelming majority (over 91%) having attained at least secondary school level education; which implies that they are quite educated about the nature of their environment. With regards to experience on urban forest management, about 70% of respondents were found to be involved in managing urban trees

(planting, nurturing and caring) for at least over 10 years. However, only about 8% of the respondents have at least over 30 years' experience in urban forest management, which implies that not many people are involved in long time management of urban trees such as planting trees around their residences or nurturing the trees within their home space or not cutting down trees in their surroundings. This weak attitude towards urban forestry might have largely contributed to degradation in the structure and composition of tree species found in Minna town over the years due to nonchalant attitude towards urban forest tree conservation and maintenance.

Common Urban Trees Species in Minna

A survey of common urban trees species in Minna (see Table 3) revealed there are about 23 tree species that are commonly planted either as single tree, line of trees or tree cluster, including trees in the downtown, old and new neighborhoods, commercial and institutional lands, and parks.

Table 3: List of Common Urban Trees Species in Minna with their Uses

S/N	Species Scientific Name	Family	Common Name	Main Use(s)
1	*Acacia albida*	*Fabaceae*	*Acacia*	Shade, Landscaping
2	*Adansonia digitata*	*Bombacaceae*	*Baobab*	Fruit, Spiritual
3	*Anogeissus sp*	*Combretaceae*	*African Birch*	Spot, Shade
4	*Azadirachta indica*	*Meliaceae*	*Neem Tree*	Sahde, Hedge
5	*Cocos nucifera*	*Arecaceae*	*Coconut Palm*	Landscaping, Fruit
6	*Daniella oliveri*	*Fabaceae*	*Ilorin Balsam*	Hedge, Shade
7	*Delonix regia*	*Fabaceae*	*Sekeseke*	Shade, Landscaping
8	*Elaeis guineensis*	*Arecaceae*	*Palm Tree*	Heddge, Landscaping
9	*Eucalyptus camaldulensis*	*Myrtaceae*	*Blue gum tree*	Hedge, Landscaping
10	*Ficus goliath*	*Moraceae*	*Odan*	Landscaping
11	*Gmelina arborea*	*Lamiaceae*	*Gmelina*	Landscaping, Sade
12	*Hyphaene thebaica*	*Arecaceae*	*Dum Palm*	Landscaping, Fruit
13	*Irvingia gabonensis*	*Irvingiacea*	*Bush mango*	Medicinal, Landscaping
14	*Khaya senegalensis*	*Meliaceae*	*Dry Zone Mahogany*	Shade, Landscaping
15	*Mangifera indica*	*Anacardiaceae*	*Mango*	Shade, Fruit
16	*Parkia biglobosa*	*Fabaceae*	*Locust Bean*	Shade, Fruit
17	*Prosopis africana*	*Fabaceae*	*African mesquite*	Shade, Landscaping
18	*Sterculia setigera*	*Malvaceae*	*Tropical Chestnut*	Shade, Hedge
19	*Tectona grandis*	*Verbenaceae*	*Teak*	Shade, Hedge
20	*Terminalia avicennoides*	*Combretaceae*	*Idi*	Shade, Hedge
21	*Terminalia catappa*	*Combretaceae*	*Umbrella tree*	Shade,
22	*Vitellaria paradoxa*	*Sapotaceae*	*Shea butter tree*	Sade, Fruit
23	*Vitex doniana*	*Verbenaceae*	*Black Plum*	Landscaping

Some of these tree species are planted in combination of two or three in the surroundings or inside compound. The main uses or purpose of planting such tree species include landscaping, shade, hedge, fruit and vegetables, spiritual, spot location or land marking and medicinal. The respondents' use or benefits from these trees points to their awareness about the importance of urban trees in providing ecosystem goods and services for their survival and healthy living. Likewise, Onyekwelu & Olaniyi (2012) observed that Urban trees species have products that are

suitable for food, medicine and nutrition supplements for healthy life. Examples include edible fruits, nuts, vegetables, and medicinal substances. City trees also help to improve energy efficiency by shading buildings (Sawka et al., 2013),

Status of Urban Forest Structure and Composition

Degradation of urban forest was assessed based on perceived changes in their structure and composition. Structure refers to the physical arrangement of various physical and biological components of an ecological system. Urban forest structure is the spatial arrangement and characteristics of vegetation in relation to other objects (e.g., buildings) within urban areas (Nowak, 1994). The results from the Ecological Risk Index (ERI) analysis of Urban Forest Structure in Minna, as presented in Table 4, revealed that tree ground cover has the highest risk index followed by reduction in tree density; deterioration in tree health and vigor; and decrease in volume of trees. Composition refers to the biodiversity of an ecological system, including the variety of genes, species, communities, and ecosystems. Among the tree composition attributes assessed, decline in tree species diversity was found to be of highest ERI, followed by decrease in native tree species; loss of beneficial tree species and; and increase in alien or exotic tree species.

Table 4: Status of Urban Forest Structure and Composition in Minna

Component	Parameter	Severity	Frequency	ERI	Rank
Structure	Decline in tree ground cover	0.81	0.85	0.689	3
	Decrease in volume of trees	0.69	0.45	0.311	8
	Reduction in tree density	0.87	0.73	0.635	5
	Deterioration in tree health and vigor	0.72	0.66	0.475	7
Composition	Decline in tree species diversity	0.91	0.82	0.746	1
	Loss of beneficial tree species	0.76	0.86	0.654	4
	Increase in allien/exotic tree species	0.74	0.73	0.540	6
	Decrease in native tree species	0.89	0.78	0.694	2

Overall, in terms of ERI level classification, The attributes within the high level class were decline in tree species diversity; decrease in native tree species and decline in tree ground cover. Those in the moderate level class were loss of beneficial tree species; Reduction in tree density; Increase in alien or exotic tree species and deterioration in tree health and vigor. Whereas, decrease in volume of trees recorded low level class of ERI. The implication is that most of the urban forest structure and composition attributes have undergone significant changes by being degraded over the years. This would have inhibited their ability to provide ecosystem services as they yielded previously (Obateru et al., 2024; Obateru et al., 2025). A healthy ecosystem is a sustainable component of the biosphere that has the ability to maintain its structure (organization), composition and function (vigor) through time and in the face of external stresses (resilience) (Mageau et al., 1995; Fanelli et al., 2025). Several studies have established relationships between different urban forest structures and specific functions such as visual quality (Schroeder 1986; Obateru et al., 2025), energy savings (McPherson, 1993), removal of atmospheric carbon dioxide (Rowntree & Nowak, 1991), urban heat island mitigation (Huang et al., 1987; Oke, 1989; McPherson, 1994), sound reduction (Cook & Van Haverbeke, 1977), wildlife habitat (DeGraaf & Wentworth, 1986), and

personal safety (Schroeder & Anderson 1984). Healthy ecosystems provide support to the human community, such as food, shelter, the capacity to assimilate and recycle wastes, clean air and water. Consequently, degradation in the face of poor resilience would have resulted in poor ecosystem services in Minna urban area.

Condition of Ecosystem Services

Ecosystem services can be defined as the benefits that people derive from nature. The Millennium Ecosystem Assessment (MEA, 2005). Ecosystem services are fundamental to the wellbeing of man. An analysis of the urban tree ecosystem services degradation status in Minna revealed the result presented in Table 5.

Table 5: Urban Tree Ecosystem Services Degradation Status in Minna

Component	Parameter	Severity	Frequency	ERI	Rank
Provisioning Services	Food (Fruit and Vegetables)	0.85	0.84	0.714	2
	Shade	0.88	0.78	0.686	4
	Fresh air	0.83	0.92	0.764	1
	Clean water	0.65	0.77	0.501	13
Supporting Services	Habitat for animals	0.92	0.64	0.589	7
	Biodiversity	0.83	0.65	0.540	10
	Infiltration	0.79	0.87	0.687	3
	Wind break	0.67	0.81	0.543	9
Regulating Services	Reducing air temperature	0.83	0.75	0.623	5
	Air purification	0.76	0.78	0.593	6
	Noise reduction	0.59	0.72	0.425	16
	Erosion control	0.79	0.62	0.490	14
	Flood control	0.59	0.87	0.513	12
	Carbon Sequestration	0.66	0.58	0.383	18
Cultural Services	Recreational	0.86	0.66	0.568	8
	Aesthetics and Beauty	0.58	0.73	0.423	17
	Spiritual values	0.61	0.85	0.519	11
	Traditional values	0.63	0.73	0.460	15

Table 5 shows that the ERI rage from lowest value of 0.383 to highest values of 0.764. Key ecosystem services with highest ERI values were fresh air, food, infiltration and shade while those with lowest values were carbon sequestration, aesthetics and beauty, and noise reduction. The impoverishment of human health due to the degradation of the ecosystems may be described as an "illness resulting from disrupted internal balances due to external stresses" (Odum, 1995; Fanelli et al., 2025). It is becoming obvious that degradation of ecosystems is increasingly the root cause of many of the disease infections within the human community (Rapport, 1998; Nova et al., 2022). Ecosystems that are sufficiently stable and biologically diverse tend to maintain the quality of human health. Degraded or collapsed ecosystems seem to have a significant impact on human health. An analysis of the literature on environmental health shows that there are many attempts to connect human health and the changing environmental conditions. Degradation of ecosystem services beyond natural thresholds, especially where these have been converted by human activities into disservices, potentially heightens risks of zoonotic diseases.

Vulnerability Indicators

Disturbance or degradation of ecosystems can have biological effects that are highly relevant to infectious disease transmission (MEA, 2005; Obateru et al., 2025). Considering the current status of urban tree forest structure, composition and ecosystem services in Minna town, the implications of findings suggest specific indicators of vulnerability to pandemic diseases, based on the following observations from findings:

i. Altered habitat leading to changes in the number of vector breeding sites or reservoir host distribution. Many ecosystem changes can alter the habitats, and hence emergence of populations of disease-transmitting vectors. Disturbance of habitats due to alterations in land cover or climatic change is considered to be the largest factor altering the risk of infectious diseases
ii. Niche invasions or transfer of interspecies hosts. The emergence of many diseases has been linked to the interface between tropical forest communities, with their high levels of biodiversity, and agricultural communities, with their relatively homogenous genetic makeup but high population densities of humans, domestic animals, and crops.
iii. Biodiversity change Biodiversity change includes issues of species replacement, loss of key predator species, and variation in species population density.
iv. Human-induced genetic changes in disease vectors or pathogens (such as mosquito resistance to pesticides or the emergence of antibiotic-resistant bacteria); and
v. Environmental contamination by infectious disease agents; such as fecal contamination of source waters.

An analysis of the literature on environmental health shows that there are many attempts to connect human health and the changing environmental conditions. Khabbaz et al. (2015) recognized 25 emerging or re-emerging infectious disease threats linked to wildlife between 2000 and 2013. According to these analyses, a key contributory factor in the increase in number and diversity of zoonotic diseases has been the extent to which humans are increasingly interacting with, and impacting upon, ecosystems, given the close relationships between human, animal and environmental health. For example, land use change has been estimated by the EcoHealth Alliance (2019) to be linked to 31% of outbreaks of emerging infectious diseases (EIDs), including HIV, Ebola, and Zika virus, which are considered connected to anthropogenic changes in tropical rainforests, with 15% of these EIDs linked to agricultural changes. Virus transmission risk has been recognized as highest from animal species that have increased in abundance and/or expanded in range by adapting to human-dominated landscapes, with domesticated species, primates and bats identified as carrying the greatest risk of zoonotic virus transmission (Kreuder et al., 2020; Fanelli et al., 2025).

CONCLUSION

The significance of the urban forest degradation and vulnerability to pandemic nexus in Minna, Nigeria, lies in the way deforestation exacerbates pandemic risks by increasing human-wildlife contact, disrupting ecosystems, and reducing access to vital resources like medicinal plants. Urban expansion and development lead to the destruction of forests, which increases the potential for zoonotic disease spillover as people and wildlife encroach on each other's habitats.

The relationships between ecological systems, their services, human society, and infectious diseases have been analyzed in this study. Urban forest degradation has continued to advance alarmingly in Minna town, contributing to increased exposure to zoonoses. As humans diminish

biodiversity by cutting down forests and building more infrastructure, they're increasing the risk of pandemics of diseases such as COVID-19. This study thus recommends urban forest restoration by planting and maintenance of trees in the neighborhoods by households, establishing more green corridors, and protecting existing green paces by urban control board. Restored ecosystems and nature-based methods emulating natural functions can enhance disease regulation as part of a linked set of societally co-beneficial ecosystem services. By reinstating lost ecosystem processes, these nature-based solutions may potentially rebuild barriers to disease organisms transferring from animals to humans. In addition, these forms of regeneration of ecosystem functions could, if combined with sustainable management of human activities and infrastructure, enhance benefits such as access to adequate supplies of clean water, which have significant roles to play in the management of disease outbreaks.

REFERENCES

Binder, C.R., Hinkel, J., Bots, P.W.G., & Pahl-Wostl, C. (2013). Comparison of frameworks for analyzing social-ecological systems. *Eco. Soc*. 18(4): 26–44. doi:10.5751/ES-05551-180426.

Cook, D. I., & Van Haverbeke, D. F. (1977). Suburban Noise Control with Plant Materials and Solid Barriers, *Research Bulletin* EM 100, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

DeGraaf, R. M., & Wentworth, J. M. (1986) Avian guild structure and habitat associations in suburban bird communities. *Urban Ecol.* 9, 399-412.

Eakin, H., & Luers, A.L. (2006). Assessing the vulnerability of social– environmental systems. *Annu. Rev. Environ. Resour*. 31: 365–394. doi:10. 1146/annurev.energy.30.050504.144352.

EcoHealth Alliance, (2019). *Infectious Disease Emergence and Economics of Altered Landscapes* - IDEEAL. EcoHealth Alliance, New York accessed 10th April 2020.). https://www.ecohealthalliance.org/wp-content/uploads/2019/09/IDEEAL_report_ final.pdf.

El-Sayed, A., & Kamel, M., (2020). Climatic changes and their role in emergence and re-emergence of diseases. *Environ. Sci. Pollut. Res.* **27**, 22336–22352.

Fanelli, A., Cescatti. A., Ciscar Martinez, J.C., Dubois, G., Ibarreta Ruiz, D., Lowe, R., Riccetti, N., Robuchon, M., Capua, I., Szewczyk, W., & Massaro, E. (2025). Assessing the risk of diseases with epidemic and pandemic potential in a changing world. *Sci. Adv*.11,eadw6363 .DOI:10.1126/sciadv.adw6363

Grove, J.M. (2009). Cities: Managing densely settled social–ecological systems. In *Principles of Ecosystem Stewardship*. Edited by Folke, C., Kofinas, G.P. & Chapin F.S. Springer, New York. pp. 281–294.

Jonathan A. P., Ulisses E.C., & Confalonieri, H. (2005). Human Health: Ecosystem Regulation of Infectious In: *Millemium Ecosystem Assessment: Diseases Ecosystems and Human Well-being: Current State and Trends*, Island Press, Washington D.C. USA.

Jones, K., Patel, N., Levy, M. (2008). Global trends in emerging infectious diseases. *Nature* 451, 990–993. https://doi.org/10.1038/nature06536

Kang, T., Jiang, Y., Yang, C., She, Y., Jiang, Z., & Li, Z. (2025). Spatial Spillover Effects of Urban Gray Green Space Form on COVID-19 Pandemic in China. *Land*, 14, 896. https:// doi.org/10.3390/land14040896

Khabbaz, R., Bell, B.P., Schuchat, A., Ostroff, S.M., Moseley, R., Levitt, A., & Hughes, J.M., (2015). Emerging and re-emerging infectious disease threats. In: Mandell, J.E., Dolin, R., & Blaser, M.J. (Eds.), *Principles and Practice of Infectious Diseases* Vol. 1. Saunders, pp. 158–177. https://doi.org/10.1016/B978-1-4557-4801-3.00014-X.

Kreuder J. C., Hitchens, P.L., Pandit, P.S., Rushmore, J., Evans, T.S., Young, C.C.W. & Doyle, M.M., (2020). Global shifts in mammalian population trends reveal key predictors of virus spillover risk. *Proc. R. Soc*. B 287, 20192736. https://doi.org/10. 1098/rspb.2019.2736.

Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M. J., & Marchetti, M. (2009). Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *Forest Ecology and Management*, *259*(4), 698–709. https://doi.org/10.1016/j.foreco.2009.09.023

Mageau, M. T., Costanza, R., & Ulanowicz, R. E., (1995). The Development and Initial Testing of a Quantitative Assessment of Ecosystem Health. *Ecosystem Health*, Vol. 1, pp. 201-213.

Mattson, K. M., & Angermeier, P. L. (2006). Integrating Human Impacts and Ecological Integrity into a Risk-Based Protocol for Conservation Planning. *Springer Science* Business Media.

McPherson, E. G. (1993). Evaluating the cost effectiveness of shade trees for demand-side management. *Electricity J*. 6, 57-65.

McPherson, E. G. (1994). Cooling urban heat islands with sustainable landscapes. In *The Ecological City, Preserving and Restoring Urban Biodiversity* (Platt, R. H. Rowntree, R. A. & Muick, P. C. ed.), pp. 151-71. University of Massachusetts Press, Boston, MA.

MEA (2005). *Ecosystems and Human Well-Being: Health* Synthesis. WHO Millemium Ecosystem Assessment, Geneva, 64.

Nova, N., Athni, T. S., Childs, M. L., Mandle, L., & Mordecai, E. A., (2022). Global change and emerging infectious diseases. *Infect. Dis.* **14**, 333–354.

Nowak, F. (1994). Understanding the structure of urban forests. *Journal of Forestry* 92:42–46.

Obateru, R.O., Okhimamhe, A.A., Fashae, O.A., Aweda, E., Dragovich, D., & Conrad, C. (2024) Community-based assessment of the dynamics of urban landscape characteristics and ecosystem services in the rainforest and guinea savanna ecoregions of Nigeria. *J Environ Manage.* Jun;360:121191. doi: 10.1016/j.jenvman.2024.121191. Epub 2024 May 17. PMID: 38759552.

Obateru, R.O., Okhimamhe, A.A., Fashae, O.A., Schürmann., A., Teucher, M., & Conrad, C. (2025). Insights into Landscape Structure Change in Urbanising Rainforest and Guinea Savanna Ecological Regions of Nigeria. *Environmental Management* **75**, 1216–1238. https://doi.org/10.1007/s00267-025-02118-0

Odum, E. P. (1995). Profile Analysis and Some Thoughts on the Development of the Interface Area of Environmental Health. *Ecosystem Health*, Vol. 1, pp. 41-45

Ojanuga, A.G. (2006). *Agroecological Zones of Nigeria Manual*. FAO/NSPFS, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria, 124 pp.

Onyekwelu, J.C. & Olaniyi, D.B. (2012). Socioeconomic importance of Urban and peri-urban forests in Nigeria. In: Research and Capacity building for agricultural transformation in Nigeria (Adebayo et al. (eds)). *Proceeding of 6th Annual conference of SAAT*, FUTA, 7-9th Nov., 2012; pp 200 – 210.

Patz, J.A., Graczyk, T.K., Geller, N., & Vittor, A.Y. (2000). Effects of environmental change on emerging parasitic diseases. *Int J Parasitol*, 30, 1395–1405.

Rapport, D.J., Christensen, N., Karr, J. R., & Patil, G.P., (1998). *Sustainable Health of Humans and Ecosystems*, unpublished report.

Rowntree, R., & Nowak, D. J. (1991). Quantifying the role of urban forests in removing atmospheric carbon dioxide. *J. Arboricult.* 17, 269-75.

Roy, S, Byrne J, & Pickering C. (2012). A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban For Urban Green* 11:351–363

Sawka, M., Millward, A. A., Mckay, J., & Sarkovich, M. (2013). Growing summer energy conservation through residential tree planting. *Landscape and Urban Planning*, *113*, 1–9. https://doi.org/10.1016/j.landurbplan.2013.01.006

Schroeder, H. W. (1986). Estimating park tree density to maximize landscape aesthetics. *J. Environ. Manage.* 23, 325-33.

Schroeder, H. W., & Anderson, L. M. (1984). Perception of personal safety in urban recreation sites. *J. Leisure Res*. 16, 178-94.

Shwartz A, Turbe´ A, Simon L, & Julliard R. (2014). Enhancing urban biodiversity and its influence on city-dwellers: an experiment. *Biol Conserv* 171:82–90

Singhal, V., Jinger, D, Rathore, A.C., Pal R., Samal, I., Bhoi, T.K., Paramesh, V., Fahad, S., Jaremko, L., Abdelsalam, N.R. & Jaremko, M. (2024). COVID-19, deforestation, and green economy. *Front. For. Glob. Change* 6:1305779. doi: 10.3389/□gc.2023.1305779

Taylor, L.H., S.M. Latham, & Woolhouse, M.E.J. (2001). Risk factors for human disease emergence. *Phil. Trans. Soc.* Lond. B., 356, 983–989.

Tollefson, J. (2020). Why deforestation and extinctions make pandemics more likely. *Nature*, *584*(7820), 175–176. https://doi.org/10.1038/d41586-020-02341-1

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A. and Schiller, A. (2003). "A Framework for Vulnerability Analysis in Sustainability Science," *Proceedings of the National Academy of Sciences* US 100, 2003, pp. 8074- 8079. doi:10.1073/pnas.1231335100

United Nations (2018). *World urbanization prospects: the 2018 revision. Economic and social affairs*. https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf. Accessed 17 Oct 2018

Urban Forestry and Woodlands Advisory Committees Network- UFWACN (2016). Introducing England's urban forests: Definition, distribution, composition and benefits. *Urban Forestry and Woodlands Advisory Committees Network*, England.

Yamane, T. (1967). *Statistics*: *An Introductory Analysis*. Harper and Row, New York, USA