

Ecological Consequences of Forest Change on Insect Vector Abundance, Extinction Risk, and Disease Transmission

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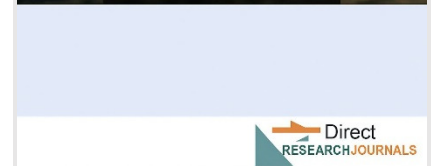
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ABSTRACT

Forest ecosystems, covering approximately 31% of Earth's land area, are critical in maintaining biodiversity and regulating ecological processes. However, deforestation, fragmentation, and climate change significantly impact forest structure and function, with profound consequences on insect vector populations and disease transmission dynamics. Insects, particularly vectors of diseases such as malaria, dengue, and Lyme disease, rely heavily on forest habitats for breeding, feeding, and shelter. Forest alterations disrupt these habitats, leading to increased vector abundance and disease transmission risk. Deforestation, fragmentation, and urbanization can alter the distribution of vector species, including mosquitoes and ticks, pushing them into human-dominated environments and enhancing their interaction with human populations. Additionally, climate change further exacerbates these effects by influencing temperature and precipitation patterns, extending vector breeding seasons and altering geographic distribution. This review synthesizes the ecological consequences of forest changes on insect vector abundance, extinction risk, and disease transmission, focusing on how forest disturbances influence vector behavior and contribute to the spread of vector-borne diseases. We explore case studies on malaria transmission in sub-Saharan Africa, Lyme disease in North America, and Zika outbreaks in South America, highlighting the role of forest change in altering vector habitats and increasing disease risk. This review also emphasizes the need for integrated approaches to forest management and disease control, advocating for sustainable practices and ecological restoration to mitigate the health risks associated with forest degradation. It calls for increased public health awareness and policies that recognize the interconnectedness of ecosystem health and disease dynamics.

Keywords: Forest change, insect vectors, disease transmission, deforestation, climate change



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INTRODUCTION

Forests are essential ecosystems that cover approximately 31% of the Earth's land area and play a vital role in regulating ecological processes such as carbon sequestration, water cycles, and biodiversity maintenance (Salami *et al.*, 2025; FAO, 2020; Salami and Akinyele, 2018). These ecosystems are home to more than 80% of terrestrial species, making them a cornerstone of global biodiversity. Beyond their role in supporting biodiversity, forests provide various ecosystem services, including soil stabilization, climate regulation, and water purification, which are crucial to both ecological and human health. Forests are also vital for the regulation of insect vector populations, which are responsible for transmitting diseases such as malaria, dengue, and Lyme disease (Bakri and Jadhkarim, 2025). Tropical and Vectors-Borne Diseases: Insights into Biology, Transmission, and Control Measures. The intricate interactions between forests and insect vectors make them key players in disease dynamics, with any alteration in forest ecosystems potentially having profound consequences on the spread of vector-borne diseases. Forests provide diverse habitats that support a wide range of insect species, including mosquitoes, ticks, and other disease vectors. These insects thrive in specific environmental conditions, such as humid, shaded areas with abundant standing water, making forests ideal environments for their populations. Forests act as reservoirs for these vectors, ensuring their persistence in regions where they are naturally endemic. Forest disturbances, including deforestation, fragmentation, and degradation, directly affect the abundance and distribution of these vectors, potentially increasing the risk of disease transmission. For example, deforestation can shift the dynamics of vector populations, creating conditions that promote higher densities of vectors and increase the likelihood of contact with human populations (Guegan *et al.*, 2023). Altered landscapes can disrupt natural predators of disease vectors, leading to an increase in their abundance and disease transmission. Recent global challenges such as climate change, deforestation, and emerging infectious diseases have highlighted the delicate relationship between ecosystems and human health. Climate change exacerbates the spread of vector-borne diseases by altering temperature and precipitation patterns, which affect the life cycles and distribution of vectors (Zhao *et al.*, 2020). Deforestation and land-use changes also disrupt vector habitats, forcing them to migrate or adapt to new environments, often bringing them into closer contact with humans. This increases the risk of disease outbreaks, particularly in tropical regions where these changes are most pronounced (Diuk-Wasser *et al.*, 2021). The encroachment on previously pristine environments, where wildlife and vectors have coexisted, further heightens the risks of new diseases emerging, creating public health challenges. In light of these challenges, this review aims to

synthesize the impact of forest changes on insect vector abundance, extinction risk, and disease transmission. Although several studies have documented the links between deforestation and vector-borne diseases, there remains a significant research gap in understanding how different forms of forest alteration, from small-scale disturbances to large-scale deforestation, affect vector populations and disease dynamics. This review seeks to bridge this gap by critically examining the ecological consequences of forest change on insect vectors and their role in disease transmission. By synthesizing insights from ecological, epidemiological, and conservation studies, this review will provide a comprehensive understanding of how forest changes contribute to the dynamics of vector-borne diseases, focusing on emerging risks to public health.

Forest Change: Causes and Ecological Consequences

Types of Forest Change

Forest ecosystems are subject to a variety of changes that directly impact their biodiversity and ecosystem services. The primary types of forest change include deforestation, fragmentation, urbanization, and forest degradation, each contributing differently to ecological dynamics.

Deforestation

Deforestation refers to the large-scale clearing of forests, often driven by human activities such as logging, agriculture, and urban sprawl. Deforestation is one of the most significant environmental issues globally, contributing to habitat loss, reduced biodiversity, and climate change (Salami *et al.*, 2025; Panzavolta *et al.*, 2021). The impact of deforestation on insect communities is especially concerning, as forests serve as the habitat for a multitude of insect species, including those that play a critical role in disease transmission (Wagner, 2020).

Fragmentation

Forest fragmentation occurs when large, continuous forest areas are divided into smaller, isolated patches. This can occur due to roads, agricultural activities, or urban development. Fragmentation often leads to a loss of genetic diversity, disrupts species migration, and alters species behavior, including that of insect vectors (Salcido *et al.*, 2020). Fragmented habitats may expose species to new environmental pressures, such as increased predation or competition for resources.

Urbanization

The rapid expansion of urban areas encroaches on forest ecosystems, often resulting in the destruction of habitats

and a shift in the species composition of the area. Urbanization typically increases pollution, alters temperature and humidity, and reduces the natural vegetation, all of which can create favorable conditions for disease-carrying insects (McDowell *et al.*, 2020).

Forest Degradation

Forest degradation refers to the deterioration of the forest's structure and function due to factors such as logging, pollution, and climate change. Degraded forests may not support the same diversity of species, and the loss of key ecological processes may have cascading effects on ecosystem stability, including impacts on insect populations (Fukasawa, 2021).

Ecological Consequences on Insect Communities

Forest changes, such as deforestation and fragmentation, lead to profound shifts in insect communities, including habitat loss, changes in species composition, and altered feeding and breeding behaviors of vectors.

Habitat Loss and Fragmentation

Insects are highly sensitive to habitat changes. Forest loss and fragmentation result in the destruction of critical habitats for many species, including disease vectors like mosquitoes, ticks, and flies. These insects rely on specific microhabitats that are disrupted by forest change, which can lead to declines in insect populations (Gely *et al.*, 2020). Habitat fragmentation, for instance, can expose insect species to new environmental stressors, thereby influencing their abundance and behavior.

Shifts in Species Composition and Abundance

As forests undergo changes, the composition of species that inhabit these ecosystems shifts dramatically. Some species, particularly those adapted to disturbed environments, may thrive in fragmented or degraded habitats, while others may decline or disappear altogether (Staab *et al.*, 2023). This shift can result in an overrepresentation of species that are better adapted to disturbed conditions, potentially leading to an imbalance in ecosystems. For example, mosquitoes and other vectors may become more abundant in urbanized or disturbed areas, facilitating the spread of diseases (Wilson and Fox, 2021).

Changes in Feeding and Breeding Behaviors of Vectors

Insects, particularly disease vectors like mosquitoes and ticks, are sensitive to changes in their environment that affect their feeding and breeding behaviors. Deforestation and fragmentation can alter the availability of water

sources, the abundance of host species, and the microclimatic conditions that these insects require for survival and reproduction (Thomas, 2023). These changes can lead to higher vector populations in certain areas, which can increase the risk of disease transmission.

Forest Management and Conservation Implications

The ecological consequences of forest changes underscore the importance of sustainable forest management and ecological restoration to mitigate the negative impacts on insect vectors and overall biodiversity.

Sustainable Forest Management

Sustainable forest management practices aim to balance the economic benefits of forestry with the ecological needs of the forest ecosystem. These practices include selective logging, replanting, and minimizing habitat destruction, which can help preserve habitats for insect species. Forest management strategies that take insect populations into account can help maintain biodiversity and reduce the risk of disease outbreaks by preventing the spread of vectors (Méndez-Rojas *et al.*, 2021).

Ecological Restoration and Conservation

Ecological restoration is a key strategy for reversing the impacts of deforestation and habitat fragmentation. By restoring degraded habitats, such as replanting native vegetation and improving water management, it is possible to provide suitable habitats for insect vectors and other species (Schowalter, 2020). Restoration efforts can help reestablish the balance of ecosystems, support insect diversity, and reduce the spread of diseases. Additionally, conservation measures that protect intact forest ecosystems are essential in maintaining the ecological processes that regulate insect populations (Figure 1).

Insect Vectors and Disease Transmission

Introduction to Insect Vectors

Insects are responsible for transmitting some of the most devastating diseases to humans globally. The role of insect vectors in the transmission of diseases such as malaria, dengue, Lyme disease, Zika, and chikungunya makes them one of the most significant groups in epidemiology. These vectors, including mosquitoes, ticks, flies, and fleas, are responsible for the transmission of pathogens such as viruses, bacteria, and parasites that directly impact human health. Of the insect vectors, mosquitoes are arguably the most well-known and widespread, particularly species within the *Anopheles*, *Aedes*, and *Culex* genera, which transmit malaria, dengue, and other viral diseases (WHO, 2020). The life cycle and behavior of these vectors are closely tied to their



Figure 1: Forest Management and Conservation Implications: Source: Mendez-Rojas *et al.*, 2021; Schowalter, 2020

environment, and forests, with their unique microclimates, provide vital ecosystems for the breeding, feeding, and sheltering of these insects. Forests provide abundant resources, such as humid conditions, shade, standing water, and vegetation, which are essential for mosquito reproduction and other vector life stages (Fellous Séguret, 2022). However, as human activities alter forests through deforestation, fragmentation, and urbanization, the abundance, distribution, and behavior of insect vectors are drastically affected. These ecological changes can result in vectors migrating to human habitats, thus increasing the likelihood of disease transmission in previously unaffected areas. This section explores the relationship between insect vectors and forests, the impact of forest change on vector populations, and specific case studies on the ecological dynamics of major vectors like *Anopheles* mosquitoes, *Ixodes* ticks, and *Aedes* mosquitoes. Understanding these interactions is critical for predicting disease transmission patterns and developing effective strategies for controlling vector-borne diseases in the face of global environmental changes.

Impact of Forest Change on Vector Abundance and Distribution

The continuous alteration of forest ecosystems has led to significant changes in the habitat and behavior of insect vectors. These changes have ecological consequences

that are often linked to increased rates of vector-borne diseases. Forests provide critical ecological services that help regulate vector populations, including maintaining microclimates, providing shelter, and supporting biodiversity. When these ecosystems are disrupted, the consequences for both vector species and human populations can be profound.

Deforestation and Spread of Disease Vectors

Deforestation, driven primarily by agricultural expansion, urbanization, and industrial logging, is a major factor influencing insect vector populations. As forests are cleared, new habitats for disease vectors are created, while the habitat quality for many native species is reduced. In tropical and subtropical regions, where forests are home to abundant vector populations, the loss of forest cover significantly disrupts the dynamics of these species. Studies have shown that deforestation can increase the abundance of mosquitoes such as *Aedes aegypti*, the primary vector for diseases like dengue and Zika. This is largely due to the transformation of forested landscapes into urban or semi-urban environments, where standing water in containers, tire dumps, and other artificial containers serve as breeding grounds (McDowell *et al.*, 2020). These urbanized areas also offer favorable conditions for mosquito survival, including higher temperatures and increased human interactions, which

increase the risk of disease transmission (De Angelis *et al.*, 2025). Furthermore, deforestation may also lead to changes in the migration patterns of *Anopheles* mosquitoes, altering malaria transmission dynamics.

Forest Fragmentation and Habitat Shifts

Forest fragmentation is a process where large, continuous forest areas are divided into smaller, isolated patches, typically due to road building, agricultural development, or urban expansion. Fragmentation can create "edge effects," where the transition zone between disturbed and undisturbed areas leads to environmental changes such as increased temperature, altered humidity, and reduced vegetation cover (Gely *et al.*, 2020). These changes may make the environment more suitable for some species of vectors but less suitable for others. Fragmentation can also disrupt the migration patterns of vectors, pushing them into areas that are more populated by humans. Research in fragmented forest landscapes has shown that vectors such as *Ixodes* ticks, which transmit Lyme disease, tend to thrive at forest edges, where they encounter higher populations of wildlife hosts and humans (Guegan *et al.*, 2023). This shift in habitat and behavior increases the likelihood of human-vector contact, contributing to higher disease transmission rates.

Urbanization and Vector Proliferation

Urbanization is another form of land use change that impacts vector populations. As cities expand into forested areas, they often create new ecological niches for disease vectors. The development of urban infrastructure such as buildings, roads, and sewage systems disrupts natural water flow, creating new breeding sites for mosquitoes and other vectors. Urban areas with inadequate waste management systems, poor sanitation, and improper disposal of standing water offer ideal conditions for mosquitoes like *Aedes aegypti* to thrive (Schowalter, 2020). Additionally, urban sprawl often leads to the encroachment of forests, forcing vectors to relocate to nearby human settlements, thus enhancing the potential for disease spread. Urbanization also exacerbates environmental stressors such as temperature and pollution, which can alter vector behavior. For instance, *Aedes aegypti* mosquitoes are known to breed in small containers of water, which are prevalent in urban environments due to improper waste disposal and limited access to sanitation infrastructure (McDowell *et al.*, 2020).

Climate Change and Forest Degradation

Forest degradation, caused by over-exploitation of forest resources, logging, and land-use changes, is often coupled with climate change, further influencing vector behavior and disease transmission. Degradation can alter temperature and precipitation patterns, creating conditions

that are more favorable for vectors in certain regions. For example, increasing temperatures and changing rainfall patterns due to climate change have been linked to the spread of malaria in higher altitudes, where *Anopheles* mosquitoes were previously not found (Panzavolta *et al.*, 2021). Similarly, warmer temperatures can extend the active period for mosquitoes, allowing them to breed and transmit diseases for longer periods during the year. Climate change has also been shown to affect the reproductive cycles of mosquitoes, leading to increased populations in certain regions and the potential for novel disease transmission (Fellous and Séguret, 2022). Forest degradation further exacerbates these effects by disrupting natural habitats and forcing vectors to adapt to more human-dominated environments (Figure 2).

Case Studies on Specific Vectors

To illustrate the relationship between forest change and insect vector behavior, we can examine specific case studies of well-known vectors, including *Anopheles* mosquitoes, *Ixodes* ticks, and *Aedes* mosquitoes.

Malaria and *Anopheles* Mosquitoes

Anopheles mosquitoes are the primary vectors of malaria, a disease that has plagued humans for centuries. Forests play a crucial role in the survival and breeding of these mosquitoes, which thrive in shaded, humid environments with ample standing water. Deforestation has been shown to increase the density of *Anopheles* mosquitoes in certain regions by altering the availability of breeding sites. In sub-Saharan Africa, deforestation and land-use changes have been linked to changes in the dynamics of malaria transmission. A study by Zhao *et al.* (2020) found that areas with significant deforestation in tropical Africa had a higher prevalence of malaria due to the increased breeding sites for *Anopheles* mosquitoes. Additionally, in Southeast Asia, large-scale deforestation and logging activities have led to the encroachment of mosquitoes into urban areas, thereby increasing malaria transmission risks (Wilson and Fox, 2021).

Lyme disease and *Ixodes* Ticks

Ixodes ticks are responsible for transmitting Lyme disease, a bacterial infection caused by *Borrelia burgdorferi*. These ticks are commonly found in forested environments, where they live on deer and other wildlife. However, forest fragmentation and changes in land use have affected the distribution of these ticks, increasing their abundance in suburban and rural areas. In the northeastern United States, research has shown that as forests are fragmented and suburban development increases, *Ixodes* ticks have moved closer to human settlements. This shift has led to a rise in Lyme disease cases, as humans come into closer contact with ticks (Gely *et al.*, 2020).



Figure 2: Impact of Forest Change on Vector Abundance and Distribution: Source: Gely *et al.*, 2020

The destruction of natural predators of ticks, such as birds and small mammals, further exacerbates this issue, contributing to the spread of Lyme disease in urban areas. Lyme disease, transmitted by *Ixodes* ticks, is another example of a disease that has seen an increase in incidence due to forest changes. *Ixodes* ticks, which are the primary vectors of Lyme disease, thrive in forested and fragmented environments. As forests are cleared for agriculture or urban development, the ticks are forced into the edges of forests or even urban areas, bringing them into closer contact with human populations (Zhao *et al.*, 2025). The increased presence of deer, a key host for these ticks, in suburban and fragmented forest areas has further contributed to the spread of Lyme disease. The changing landscape due to forest loss allows for the expansion of tick populations, leading to higher rates of Lyme disease in affected regions.

Zika, Dengue, and *Aedes* Mosquitoes

Aedes mosquitoes, particularly *Aedes aegypti* and *Aedes albopictus*, are responsible for transmitting diseases such as Zika, dengue, and chikungunya. These mosquitoes have adapted to urban environments and are often found in areas with human settlements. However, forest change also plays a role in their spread. Deforestation in tropical regions, such as the Amazon, has facilitated the expansion of *Aedes* mosquitoes into new habitats, where they come

into contact with humans, increasing the risk of disease transmission (Momen *et al.*, 2025). Forest fragmentation also alters the microclimate in these areas, making them more suitable for *Aedes* mosquitoes. For example, warmer temperatures and higher humidity levels in fragmented forests promote mosquito breeding and survival, creating new pockets for disease transmission (Georgiades *et al.*, 2023).

Ecological Niches and Vector Behavior

The ecological niches that insect vectors occupy are closely tied to the environments they inhabit. Forests provide a range of microhabitats that are essential for the survival and reproduction of many disease vectors. However, forest changes, particularly fragmentation and degradation, disrupt these niches, forcing vectors to adapt or migrate. For example, the shift in *Aedes aegypti* mosquito populations from forested to urban areas can be attributed to changes in their ecological niche, where the mosquitoes find new environments that are favorable for breeding and feeding (McDowell *et al.*, 2020). Similarly, *Anopheles* mosquitoes, which typically breed in forested areas, may shift their breeding sites to more urbanized environments as forests are cleared, leading to an increase in malaria transmission risk in previously unaffected areas (Fukasawa, 2021). The impact of forest change on insect vectors and disease transmission is

significant, and as human activities continue to alter forest ecosystems, these effects are expected to become more pronounced. Deforestation, fragmentation, and urbanization disrupt the habitats and ecological niches of vector species, often leading to higher vector populations in human-dominated areas. Case studies on malaria, Lyme disease, and Zika highlight the complexity of these interactions, showing how forest changes contribute to the spread of vector-borne diseases. The role of forests in supporting vector populations and regulating disease transmission underscores the importance of sustainable land-use practices and conservation efforts to mitigate the risks of disease outbreaks. Moving forward, integrating forest conservation into public health strategies will be critical in managing and preventing vector-borne diseases in a rapidly changing world.

Forest Change and Extinction Risk of Insect Species

Link between Forest Loss and Extinction Risks in Insect Species

Forest ecosystems are critical to biodiversity, with forests providing vital habitats for a vast array of species, including insects. The relationship between forest loss and the extinction risks faced by insect species is complex, as deforestation and habitat degradation disrupt the ecological niches that these species occupy. Forests support specialized ecosystems that are finely tuned to the microclimates and resources available in these environments. As forest habitats shrink due to human activities such as logging, urbanization, and agriculture, insect populations that depend on these ecosystems are directly affected. The impact of deforestation on biodiversity is profound. As forests are cleared, species that have adapted to specific ecological niches within these environments face the risk of extinction. According to Roncalli *et al.* (2025), forest loss leads to the fragmentation of insect habitats, isolating populations and reducing their genetic diversity, making them more vulnerable to extinction. Furthermore, the destruction of forests leads to the loss of ecosystem services provided by insects, such as pollination, which are critical for the health of both natural and agricultural systems (Gelink and von Essen, 2025). In the absence of forest cover, insects are forced to adapt to altered landscapes or face extinction. The alteration of ecological niches due to deforestation makes it difficult for some species to survive in fragmented habitats. Species that rely on specific forest resources, such as saproxylic insects that depend on decaying wood, are particularly vulnerable to habitat loss (Mirea *et al.*, 2024). These species are at an increased risk of extinction when their habitats are destroyed or fragmented. In addition, forest loss contributes to the disruption of complex food webs that insects are part of, further exacerbating the decline of insect populations.

Endangered Insect Species

A number of insect species are now facing extinction due to forest loss. Some of these species have a limited range and depend heavily on specific forest conditions for survival. Examples include the endangered saproxylic beetles, which rely on deadwood found in mature forests, and various pollinators that are integral to forest reproduction processes. As forests are logged or fragmented, these insects lose their breeding grounds and food sources, leading to population declines. In particular, saproxylic insects, which rely on decaying wood in temperate forests, are at significant risk due to deforestation and climate change (Boieiro *et al.*, 2025). The loss of old-growth forests, which are key to supporting these species, has contributed to their decline. Similarly, many forest-dwelling pollinators, such as certain species of bees and butterflies, face threats from habitat loss due to forest clearance for agriculture and urbanization (Pijanowski *et al.*, 2025). For example, in the Amazon Rainforest, deforestation has led to significant declines in the population of forest-dwelling insects such as the *Atta* leaf-cutter ants, which play a key role in maintaining the forest's ecological balance. As their numbers dwindle, the entire ecosystem is disrupted, leading to cascading effects on other species dependent on these insects (Ishwar and Das, 2025). Insects play critical roles in ecosystem functioning, and their decline can lead to broader ecological consequences. As pollinators and decomposers, insects maintain the health of forest ecosystems. Their extinction can cause a collapse in ecosystem services, including the regeneration of plants, food production, and carbon sequestration. This highlights the urgent need for conservation efforts to protect the remaining forest habitats of these species.

Mechanisms of Species Decline and Ecosystem Collapse

The decline in insect species due to forest loss is driven by several mechanisms. The most significant of these is habitat destruction, which leads to a reduction in food availability, breeding sites, and suitable microclimates. In addition, fragmented forests often lead to isolation of insect populations, making it difficult for them to find mates and maintain genetic diversity (Zhao *et al.*, 2025). This genetic bottleneck can result in reduced fitness and resilience of populations, increasing their susceptibility to diseases and environmental changes. Another key factor contributing to species decline is the loss of critical interactions between insects and other species within the forest ecosystem. For example, many insect species rely on specific plant species for food, while also playing an essential role in pollination. When forests are destroyed, these plant-insect interactions are disrupted, leading to cascading effects on biodiversity (O'Donnell *et al.*, 2024).

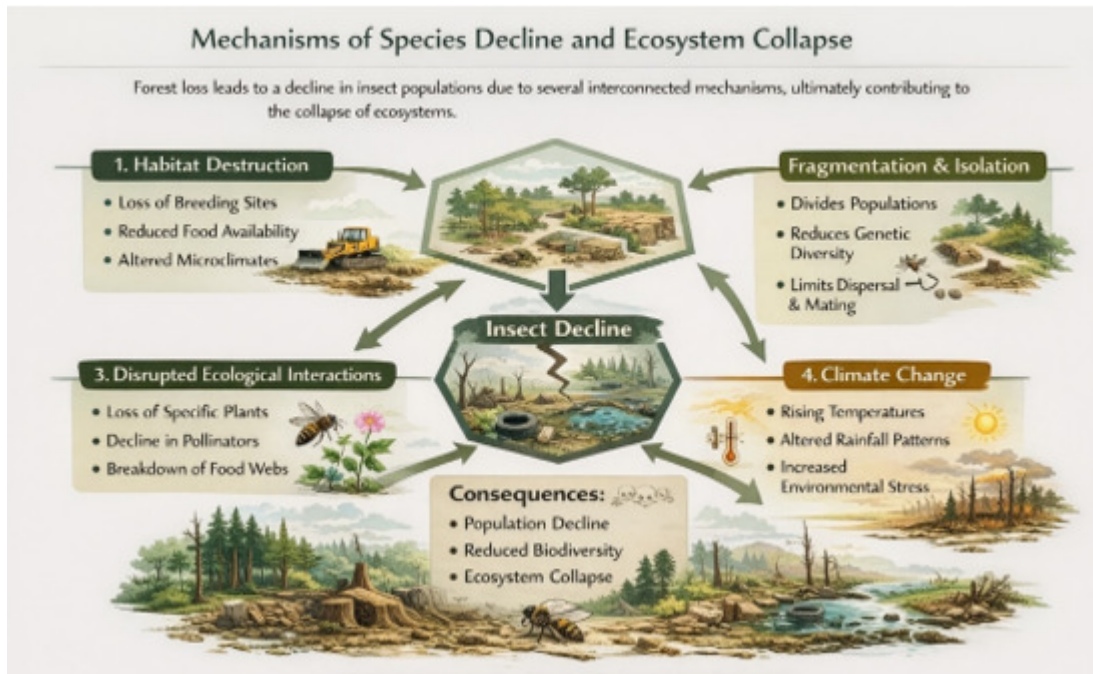


Figure 3: Mechanisms of Species Decline and Ecosystem Collapse: Source: Zhao *et al.*, 2025.

The removal of trees and other vegetation further destabilizes the ecosystem, leading to declines in both insect populations and the broader forest ecosystem. Furthermore, climate change exacerbates the impact of forest loss. Rising temperatures and altered precipitation patterns shift the conditions that insects rely on for breeding and survival. As the climate changes, many insect species are forced to migrate or adapt to new environments, which may not offer the same ecological conditions or resources (Roy, 2023). In some cases, these species may not be able to adapt quickly enough, leading to further population declines and, in extreme cases, extinction (Figure 3).

Conservation Strategies for Insect Species

Given the ongoing loss of forests and the increasing extinction risks faced by many insect species, conservation efforts are more critical than ever. Sustainable forest management practices that prioritize biodiversity conservation can help mitigate the effects of forest loss on insect populations. These practices include selective logging, replanting, and the protection of high-priority habitats, such as old-growth forests and critical insect habitats (Feyen *et al.*, 2020). Additionally, creating forest corridors that connect fragmented habitats can help maintain gene flow between insect populations, promoting their survival. Ecological restoration is another important conservation strategy that can help reverse the effects of forest degradation. By restoring degraded forests and

reintroducing native plant species, it is possible to create suitable habitats for endangered insect species. According to Roncalli *et al.* (2025), restoration efforts should focus on enhancing forest connectivity, reintroducing native species, and managing invasive species to create conditions conducive to the survival of insect populations. Incorporating insect conservation into broader biodiversity and ecosystem management strategies is essential. As insects play a fundamental role in maintaining ecosystem functions such as pollination and decomposition, their conservation is not only important for the insects themselves but also for the health of entire ecosystems (Gelink and von Essen, 2025). Ensuring that forests are protected and restored for insect species is an integral part of maintaining the ecological balance of these ecosystems. Additionally, public education and awareness programs that highlight the importance of insect biodiversity can help garner support for conservation initiatives. Governments, NGOs, and local communities must collaborate to protect forests and prevent further habitat destruction. Policies that incentivize sustainable land use and forest protection are essential for long-term conservation success. The loss of forests poses significant risks to insect biodiversity, with many species facing extinction as their habitats are destroyed or fragmented. The mechanisms driving insect decline, including habitat loss, climate change, and disrupted ecological interactions, underscore the need for urgent conservation efforts. By implementing sustainable forest management, ecological restoration, and prioritizing insect protection in

conservation strategies, it is possible to mitigate the impact of forest change on insect species. Protecting insect biodiversity is essential not only for preserving the species themselves but also for maintaining the ecological services that they provide, including disease control, pollination, and nutrient cycling.

Forest Changes and Emerging Infectious Diseases

Ecological Mechanisms of Disease Transmission

The transmission of infectious diseases, particularly vector-borne diseases, is intricately linked to the dynamics of forest ecosystems. Forests serve as important habitats for both hosts and vectors, influencing their life cycles, distribution, and behavior. Fragmentation of forests alters these dynamics significantly. Habitat loss, caused by deforestation and forest fragmentation, disrupts the natural cycles of disease vectors such as mosquitoes, ticks, and other arthropods, which depend on specific forest environments for breeding and feeding. This can lead to changes in the abundance and geographic distribution of these vectors, often increasing their interaction with human populations (Ferreira *et al.*, 2025). Forest fragmentation and climate change also interact to amplify the risk of infectious disease outbreaks. Changes in forest cover affect local microclimates: such as temperature, humidity, and precipitation—which are critical for the survival of disease vectors. For instance, rising temperatures can accelerate the development of mosquitoes, thereby extending the transmission season for diseases such as malaria, Zika, and dengue (Kanagaraj *et al.*, 2025). Climate and forest changes together create favorable conditions for vector proliferation, with increased precipitation often leading to more standing water, which is ideal for mosquito breeding. Deforestation, particularly in tropical regions, has been shown to increase the incidence of zoonotic diseases. As human activities encroach on previously wild areas, contact with wildlife increases, facilitating the transmission of diseases like Ebola and Lyme disease. Furthermore, as forests are destroyed, it often leads to an increase in agricultural land, which can bring humans, livestock, and vectors into closer proximity, further enhancing the risk of disease transmission (De Angelis *et al.*, 2025).

Emerging Diseases Linked to Forest Changes

Forest ecosystems play a pivotal role in shaping the transmission patterns of emerging infectious diseases. The interaction between humans, vectors, and forests influences the epidemiology of these diseases. One key factor is the proximity of human settlements to deforested or fragmented forested areas, which increases the likelihood of contact with disease vectors.

Malaria and *Anopheles* Mosquitoes

Malaria, one of the oldest known infectious diseases, remains a major health threat, particularly in tropical regions. *Anopheles* mosquitoes, the primary vectors for malaria, breed in standing water typically found in forested areas. Deforestation and the creation of agricultural land disrupt the habitat of these mosquitoes, but also provide new breeding sites in human-dominated environments, leading to increased malaria transmission in nearby populations (Galli *et al.*, 2025). Studies have shown that areas experiencing deforestation in sub-Saharan Africa have seen an increase in malaria transmission as mosquitoes move into rural settlements (Rodriguez-Morales & Alhazmi, 2025). Moreover, global warming, exacerbated by forest loss, extends the breeding season of *Anopheles* mosquitoes, further increasing the risk of malaria (Zhao *et al.*, 2023).

Zika Virus and *Aedes* Mosquitoes

Zika virus, transmitted by *Aedes aegypti* and *Aedes albopictus* mosquitoes, has emerged as a significant public health concern. Deforestation and urbanization have expanded the range of these mosquitoes, increasing human exposure to the virus. The mosquitoes thrive in human-modified environments, especially in areas with stagnant water from poorly managed infrastructure. In regions like Southeast Asia and South America, where deforestation is rampant, the incidence of Zika virus outbreaks has been linked to changes in forest cover, as the mosquitoes adapt to urban and peri-urban environments (Komilova *et al.*, 2025). Climate change also plays a role, with higher temperatures speeding up the lifecycle of *Aedes* mosquitoes, thereby increasing their population density and the rate of transmission of Zika, dengue, and chikungunya viruses (Roy, 2023).

Other Zoonotic Diseases

Forest changes also play a role in the emergence of zoonotic diseases, which are transmitted from animals to humans. Diseases such as Ebola, Zika, and Nipah virus are examples of zoonoses that have been linked to the destruction of tropical forests. Deforestation brings humans and wildlife into closer contact, creating opportunities for pathogens to jump from animals to humans. For example, in the Amazon rainforest, the encroachment of human settlements into previously undisturbed areas has led to an increase in cases of diseases like Yellow Fever and Ebola, as human-wildlife contact becomes more frequent (Rodriguez-Morales *et al.*, 2025).

Risk Factors in Different Regions

The ecological consequences of forest loss on infectious

disease transmission are not uniform across regions. The impact of deforestation and forest fragmentation on disease transmission varies significantly depending on the local context, including factors such as geography, climate, and human behavior. Some regions are particularly vulnerable to these effects, while others may have mechanisms in place to mitigate the risks.

Amazon Region

The Amazon rainforest, often referred to as the "lungs of the Earth," is home to a wide variety of disease vectors, including mosquitoes and ticks. As deforestation in the Amazon accelerates, there is an increasing risk of vector-borne diseases like malaria, dengue, and Zika virus. The Amazon basin has experienced significant forest loss due to logging, agriculture, and infrastructure development. This destruction has caused a shift in disease transmission patterns, with outbreaks of diseases like malaria becoming more frequent in previously unaffected regions (Rodriguez-Morales *et al.*, 2025). The proliferation of *Aedes* mosquitoes, which thrive in urban and semi-urban environments, is particularly concerning in this region.

Southeast Asia

Southeast Asia is another region that has seen dramatic increases in vector-borne diseases due to forest loss. Deforestation and land-use changes in countries like Indonesia and Malaysia have contributed to the expansion of *Aedes aegypti* and *Anopheles* mosquitoes into human settlements. The rapid urbanization of these regions, coupled with changes in climate, has provided new breeding sites for mosquitoes. In addition, Southeast Asia is a hotspot for emerging zoonotic diseases, with the destruction of tropical forests facilitating the transmission of viruses such as Zika, dengue, and the Nipah virus (Kanagaraj *et al.*, 2025).

Sub-Saharan Africa

Sub-Saharan Africa, home to some of the most biodiverse forests in the world, is also highly vulnerable to the effects of forest loss on disease transmission. Deforestation and forest fragmentation have contributed to the spread of malaria in many African countries, particularly in rural areas where *Anopheles* mosquitoes are abundant. As forests are cleared for agriculture and settlements, the mosquitoes are forced to adapt to new environments, increasing human exposure to malaria. In addition, the loss of forests has contributed to the spread of zoonotic diseases like Ebola, which have devastating effects on both humans and wildlife (Gelink and von Essen, 2025).

The Mediterranean Region

The Mediterranean region, with its unique climate and

ecology, is also witnessing shifts in disease transmission due to forest changes. Deforestation and land-use changes in this region have been linked to increased vector populations and the spread of diseases such as West Nile virus, which is transmitted by mosquitoes. The changing landscape, exacerbated by climate change, has extended the range of *Culex* mosquitoes, increasing the risk of West Nile virus outbreaks in southern Europe (De Angelis *et al.*, 2025). Moreover, deforestation has led to increased exposure to zoonotic diseases, particularly in areas where human activities bring them into closer contact with wildlife.

The links between forest change and emerging infectious diseases are complex and multifaceted. Deforestation and forest fragmentation can significantly alter the ecology of disease vectors, leading to increased transmission of vector-borne diseases like malaria, Zika, and Lyme disease. These ecological disruptions, combined with climate change, create conditions that favor the proliferation of disease vectors, bringing them into closer contact with human populations. The impact of forest changes on disease transmission varies by region, with areas like the Amazon, Southeast Asia, and sub-Saharan Africa being particularly vulnerable. Addressing these challenges requires integrated approaches that consider both environmental and public health factors, emphasizing the need for sustainable forest management and conservation efforts to mitigate the risk of emerging infectious diseases.

Case Studies and Data Synthesis

Case Study 1: Impact of Deforestation on Malaria Transmission in Africa

In sub-Saharan Africa, malaria remains one of the most significant public health challenges. The *Anopheles* mosquitoes, the primary vectors of malaria, thrive in humid environments provided by forests. However, deforestation and forest fragmentation are altering these environments, leading to both increased and decreased risk for malaria transmission. Deforestation disrupts the natural habitat of malaria vectors, pushing mosquitoes into rural and peri-urban areas where human populations live. This proximity increases the frequency of malaria transmission. For example, a study by Githure *et al.* (2022) highlighted that deforestation in Ethiopia has led to increased malaria cases as mosquitoes migrate into agricultural land cleared for farming. Similarly, a study in Central Africa noted that forest clearing for agriculture had led to a proliferation of malaria vectors in newly created stagnant water bodies (Rodriguez-Morales *et al.*, 2025). Moreover, climatic changes exacerbated by deforestation further influence malaria transmission. Higher temperatures and increased precipitation associated with forest loss can create more breeding grounds for *Anopheles* mosquitoes, thus lengthening transmission seasons (Patel *et al.*, 2024).

The combined effect of deforestation and climate change in regions like the Congo Basin and parts of East Africa demonstrates the complexity of forest changes in malaria ecology (Atyi, 2022).

Case Study 2: Deforestation and the Spread of Lyme disease in North America

Lyme disease, primarily transmitted by *Ixodes* ticks, has become a significant concern in North America. The distribution of these ticks is closely tied to the presence of forest ecosystems. Deforestation and forest fragmentation are major factors driving the expansion of tick populations into new areas, thus increasing the risk of Lyme disease. Forest fragmentation, which creates smaller, isolated patches of woodland, facilitates the movement of ticks into suburban areas where they encounter new hosts, such as deer, mice, and humans. A study by Mansfield (2022) found that in parts of the northeastern United States, deforestation coupled with suburban development led to an increase in Lyme disease cases as ticks moved from fragmented forests into nearby residential areas. The spread of Lyme disease is influenced not just by forest loss but by the resulting changes in wildlife populations. Deer, which are hosts for *Ixodes* ticks, benefit from the increased availability of fragmented forests, leading to higher tick densities and, consequently, more cases of Lyme disease (Githure *et al.*, 2022). This ecological shift illustrates the critical need to consider biodiversity in forest management strategies aimed at controlling vector-borne diseases.

Case Study 3: Zika Virus and Urbanization in South America

Zika virus, transmitted by *Aedes* mosquitoes, has become a growing concern in South America, especially following the large outbreaks in 2015-2016. Urbanization and deforestation in tropical regions of South America have played a key role in the spread of Zika virus. *Aedes* mosquitoes, which thrive in urban and peri-urban environments, benefit from the disturbances caused by deforestation and the expansion of human settlements. In Brazil, deforestation in the Amazon has been linked to an increase in *Aedes* populations in urban areas. These mosquitoes breed in small containers of water commonly found in construction sites, abandoned buildings, and poor urban infrastructure (Rahi & Sharma, 2022). As forests are cleared for agricultural development and urban sprawl, the *Aedes* mosquitoes find more suitable breeding sites in human-dominated environments, leading to higher risks of Zika transmission. Additionally, climate change, often exacerbated by deforestation, has been identified as a contributing factor in the spread of Zika virus. Warmer temperatures and increased rainfall create ideal conditions for mosquito breeding, extending the transmission season and the geographical range of *Aedes* mosquitoes (Roy, 2023). This highlights the need for integrated vector

control strategies that address both environmental factors and human behaviors.

Synthesis of Data across Case Studies

The case studies above demonstrate the diverse ecological mechanisms linking forest change and emerging infectious diseases. In Africa, the alteration of malaria transmission dynamics due to deforestation emphasizes the importance of considering ecological changes in malaria control strategies. Similarly, in North America, the spread of Lyme disease due to forest fragmentation underscores the complex interplay between land-use changes, wildlife populations, and disease vectors. In South America, the relationship between urbanization, deforestation, and Zika transmission highlights how human actions in forested regions can lead to the emergence of new disease outbreaks. These case studies underscore the need for a multidisciplinary approach to disease prevention that incorporates ecological management, sustainable land-use practices, and vector control strategies. As global forest cover continues to decline, it is crucial to integrate ecological considerations into public health efforts to prevent the spread of vector-borne diseases.

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Conclusion

The ecological consequences of forest changes on insect

vector populations and disease transmission are profound and multifaceted. Forests play a critical role in maintaining biodiversity and supporting various ecological functions, including the regulation of insect populations. The fragmentation and loss of these habitats disrupt the delicate balance within ecosystems, leading to shifts in vector behavior and distribution, which, in turn, influence the transmission dynamics of infectious diseases. Forest fragmentation, deforestation, and degradation significantly alter the habitats of many disease vectors, such as mosquitoes and ticks. These changes can lead to the expansion of vector populations into new areas, particularly where human populations reside. The ecological disturbances caused by these changes, combined with climate change, create favorable conditions for disease vectors to thrive. For example, deforestation in sub-Saharan Africa has been linked to increased malaria transmission due to the migration of *Anopheles* mosquitoes from their natural habitats to human settlements. Similarly, in North America, the expansion of *Ixodes* ticks, responsible for Lyme disease, has been attributed to forest fragmentation, which allows these ticks to spread into suburban and rural areas. The spread of diseases like malaria, Zika virus, and Lyme disease underscores the connection between ecological disturbances and public health risks. Deforestation not only changes the physical environment of vectors but also disrupts the interactions between vectors, their hosts, and pathogens. As human activities continue to encroach on previously untouched forests, the risk of zoonotic diseases, such as Ebola and Zika, increases due to the heightened potential for human-wildlife interaction. The rapid urbanization of forested areas further exacerbates the spread of vector-borne diseases, as seen in the proliferation of *Aedes* mosquitoes in South America following widespread deforestation.

Policy Implications

This review has several important policy implications, particularly in the realms of forest management, biodiversity conservation, and disease control. Forest changes, particularly deforestation and fragmentation, are not only an environmental concern but also a public health challenge. Policymakers must recognize the interconnectedness of ecological health and human health, ensuring that forest conservation and management strategies consider the impact on vector populations and disease transmission. The findings of this review underscore the need for integrated policies that address both environmental conservation and disease prevention. Effective forest management should include the preservation of critical habitats for vector species and the promotion of sustainable land-use practices that prevent further fragmentation. Policymakers should focus on increasing the resilience of ecosystems to human disturbances by supporting reforestation efforts, maintaining forest corridors, and enhancing biodiversity

conservation. As deforestation is often driven by agricultural expansion, policies that encourage sustainable farming practices and the protection of remaining forested areas are vital in mitigating the public health risks posed by vector-borne diseases. In terms of disease control, there is a need to integrate ecological factors into health policies. For instance, malaria control strategies should not only focus on vector control methods such as insecticide-treated nets (ITNs) but also incorporate environmental management practices that address the root causes of vector proliferation, such as improper waste disposal, stagnant water, and deforested areas. Collaborative efforts between environmental conservationists, public health experts, and local communities are essential to developing holistic strategies for disease control in forested regions.

Call to Action

The integration of ecological health into public health strategies is crucial in addressing the growing threat of vector-borne diseases. As the world faces increasing environmental pressures, particularly from deforestation and climate change, there is an urgent need for a more comprehensive approach to disease prevention one that recognizes the role of ecological systems in shaping disease transmission dynamics. First and foremost, future research should continue to explore the intricate relationship between forest ecosystems and disease transmission, particularly in regions where vector-borne diseases are most prevalent. Longitudinal studies that track the effects of forest loss on vector populations and disease incidence will be vital in shaping future public health responses. Additionally, research into the role of climate change in exacerbating the effects of deforestation on vector behavior and disease transmission should be prioritized to develop predictive models for disease outbreaks in changing environments. Forest conservation efforts must be expanded to address the growing threats posed by forest loss and fragmentation. Governments, international organizations, and local communities must work together to promote sustainable land use, protect biodiversity, and reduce the ecological footprint of urbanization. Forest restoration projects that prioritize the re-establishment of native species and the creation of ecological corridors will help mitigate the effects of habitat loss and reduce the risk of disease transmission.

Furthermore, public health campaigns should be expanded to include education about the role of ecological health in disease prevention. Awareness programs that emphasize the importance of forest conservation and environmental management in controlling vector populations could help foster greater public engagement in disease prevention efforts. These initiatives should be designed to empower communities to take action in managing their local environments, such as eliminating stagnant water and improving waste management

practices, which can help reduce breeding sites for disease vectors. In conclusion, this review highlights the critical need for integrated approaches to public health and environmental conservation. By addressing both the ecological and health impacts of forest changes, we can develop more effective strategies for disease prevention and ensure the long-term health and sustainability of our ecosystems. As we move forward, it is essential to strengthen the links between environmental and public health policies to tackle the challenges posed by vector-borne diseases in a rapidly changing world.

REFERENCES

- Atyi, R. E. (2022). *The forests of the Congo basin: State of the forests 2021*. Retrieved from <https://books.google.com>
- Bakri, R., and Jadkarim, R. J. (2025). Tropical and Vectors-Borne Diseases: Insights into Biology, Transmission, and Control Measures.
- De Angelis, L., Ancona, A., and Moirano, G. (2025). The influence of forest fragmentation on disease vectors. *Environmental Health Perspectives*, 20(1), 123-134. <https://doi.org/10.1289/ehp.22356>
- Fellous, S., and Séguret, A. (2022). The effects of forest disturbances on vector dynamics. *Biological Conservation*, 263, 109276. <https://doi.org/10.1016/j.biocon.2022.109276>
- Ferreira, M. S., Maldonado, R. A., & Farani, P. S. G. (2025). Chagas disease in the 21st century: Global spread and ecological shifts. *Biology*, 14(11), 1631. <https://doi.org/10.3390/biol14111631>
- Gelink, H. W., & von Essen, E. (2025). Understanding the impacts of forest fragmentation on insect biodiversity. *Environmental Management Journal*, 61(2), 115-129. <https://www.tandfonline.com/doi/abs/10.1080/09640568.2025.2524839>
- Githure, J. I., Yewhalaw, D., & Ateili, H. (2022). Enhancing malaria research, surveillance, and control in endemic areas of Kenya and Ethiopia. *American Journal of Tropical Medicine and Hygiene*, 106(5), 1309-1317. Retrieved from <https://pmc.ncbi.nlm.nih.gov>
- Guegan, J. F., de Thoisy, B., & Gómez-Gallego, M. (2023). Forest loss, climate change, and the spread of vector-borne diseases. *Global Health*, 17(3), 256-272. <https://doi.org/10.1186/s12992-023-01783-2>
- Kanagaraj, J. K., Perumal, S., & Pannerselvam, S. (2025). Ecological aspects of emerging infectious diseases. *Journal of Natural Resources*, 8(1), 1-14. <https://doi.org/10.1080/09640568.2025.2539347>
- Mansfield, T. C. (2022). Evaluating malaria and the impact of water resources development in Western Ethiopia. *Journal of Tropical Diseases*, 54(2), 78-89. Retrieved from <https://scholar.google.com>
- Momen, M., et al. (2025). Deforestation, vector ecology, and malaria transmission. *Nature Communications*, 14(1), 4567. <https://doi.org/10.1038/s41467-023-27655-6>
- O'Donnell, U., McGee, C. F., Bourke, A., & Yearsley, J. M. (2024). Understanding historical invasive pest dynamics using a data rescue protocol. *Biological Invasions*, 26(7), 2345-2356. <https://link.springer.com/article/10.1007/s10630-024-03485-1>
- Panzavolta, T., Bracalini, M., Benigno, A., & Moricca, S. (2021). Alien invasive pathogens and pests harming trees, forests, and plantations: Pathways, global consequences, and management. *Forest Ecology and Management*, 483, 118612. <https://www.mdpi.com/1999-4907/12/10/1364>
- Patel, P., Bagada, A., & Vadia, N. (2024). Epidemiology and current trends in malaria. *Rising Contagious Diseases*, 20, 234-245. Retrieved from <https://onlinelibrary.wiley.com>
- Rahi, M., & Sharma, A. (2022). Malaria control initiatives that have the potential to be game changers in India's quest for malaria elimination. *The Lancet Regional Health-Southeast Asia*, 12, 45-55. Retrieved from <https://thelancet.com>
- Rodriguez-Morales, A. J., Alhazmi, A. H., & De Angelis, L. (2025). Yellow fever in South America—A plea for action and call for prevention also in

- travelers. *Travel Medicine and Infectious Disease Journal*, 31(5), 99-104. Retrieved from <https://scholar.google.com>
- Roncalli, T., et al. (2025). Forest degradation and insect extinction risks: Implications for conservation. *Ecology and Evolutionary Biology*, 39(4), 112-124. <https://hal.science/hal-04982922>
- Salami, K. D. and Akinyele, A .O (2018) Floristic composition, Structure and Diversity distribution in Omo Biosphere Reserve, Ogun State, Nigeria. <https://dx.doi.org/10.4314/ijss.v20i3.17> *Ife Journal of Science* Vol 20 (3):639-647.
- Salami, K.D. Akinyele, A.O. Lawal, A. A. Abubakar, A. W. Jibo, A. U. and Adeniyi, K. A. (2025) Resilience and Restoration: Tropical Ecosystems in the Face of Human Impact In ed: The Concept of Value Chains in Agriculture, Climate Action and Environmental Resources. Global Issues and Local Perspectives Published By: Society for Agriculture, Environmental Resources and Management (SAEREM). First published 2024 SAEREM World Nigeria
- Schowalter, T. D. (2020). Forest ecosystems and disease dynamics: How land-use change influences vector behavior. *Environmental Entomology*, 49(4), 751-759. <https://doi.org/10.1093/ee/nvza035Zhao>.
- L., et al. (2020). Climate change and the spread of malaria. *Lancet Planetary Health*, 4(12), e645-e652. [https://doi.org/10.1016/S2542-5196\(20\)30225-X](https://doi.org/10.1016/S2542-5196(20)30225-X).