Vidyodaya Journal of Humanities and Social Sciences

VJHSS (2025), Vol. 10 (02)

A Review of Integrating Geospatial Technologies and Artificial Intelligence for Habitat Connectivity Assessment in Fragmented Landscapes

H. M. B. S. Herath

Department of Geography, University of Sri Jayewardenepura, Sri Lanka

Article Info

Article History:
Received 08 Aug 2024
Accepted 28 July 2025
Issue Published Online
01 July 2025

Key Words:
Geospatial Technology
Remote Sensing
Artificial Intelligence
Habitat Connectivity
Fragmented Landscapes

*Corresponding author
E-mail address:
badrahearath@sjp.ac.lk

https://orcid.org/0000-0002-6697-0742

Journal homepage:
http://journals.sjp.ac.lk/index.php/vjhss

http://doi.org/10.31357/fhss/vjhss.v10i02.05

VJHSS (2025), Vol. 10 (02), pp. 60-70

ISSN 1391-1937/ISSN 2651-0367 (Online)

ABSTRACT

Breaking down natural habitats presents a major threat to biodiversity through disrupted ecological connections, mutated species paths, and enhanced separation of territorial areas. Most of these difficulties require advanced analytical tools that combine geographic information technology with Artificial intelligence (AI) capabilities to do better habitat connectivity assessments. This review investigates the modern development of remote sensing technologies alongside Geographic Information Systems (GIS) and AI-powered models for habitat fragmentation assessment and conservation planning designs. Monitoring habitat transformations through time becomes possible through high-resolution LiDAR-based satellite imagery and using Unmanned Aerial Vehicles-based (UAV-based) monitoring, which delivers extensive spatial data about habitat alterations. The analysis of ecological corridors and the assessment of fragmentation metrics become possible by implementing two GIS-based modeling techniques, consisting of least-cost path analysis and circuit theory modeling. Deep learning frameworks, including Convolutional Neural Networks (CNNs) and Object-Based Image Analysis (OBIA), have revolutionized land cover classification while simultaneously enabling automated connectivity assessments by enhancing accuracy levels. The application of AI in ecological assessments is hindered by challenges such as limited data availability, poor model generalization, and a lack of interpretability in predictive models. The study followed a systematic review approach to formulate the review article to address the research focus. The review research has been designed to achieve three objectives: to evaluate the integration of AI techniques for improving data access at fine scales, enhancing ecological connectivity metrics for sustainable habitat management, and to examine the challenges and opportunities of using AI and GIS in habitat connectivity, focusing on data access, model interpretability, and classification consistency.

Introduction

Fragmentation of habitats is one of the most significant threats to the maintenance of biological diversity in the world. Habitat fragmentation is mainly attributed to the anthropogenic land use alteration including deforestation, agricultural expansion, and urbanization (Floreano & de Moraes, 2021; Alegbeleye et al., 2024). Simplification refers to the situation where continuous habitats are fragmented, splintered, or cut into small fragment pieces, thereby reducing the connectivity of the ecological space, the ability of species to move within the space, and making species more susceptible to extinction (Prasad & Ramesh, 2019). Disruption of connectivity can have great consequences on such ecosystem processes as species movement, gene flow, and resource distribution (Gidey et al., 2017).

The habitat connectivity is critical to be assessed, especially for the identification of species' requirements and mainly for developing the appropriate conservation measures. Field-based surveys have some limitations when used to survey large geographical areas. For this reason, they are limited in spatial and temporal coverage (Mohd Noor et al., 2018). Over the years, GIS and Remote Sensing (RS) technologies have helped in providing spatial data that makes it easier to study habitat connectivity over space and time (Chen et al., 2020). Landsat, Sentinel-2, and MODIS imagery, along with aerial images of Unmanned Aerial Vehicles (UAVs) facilitate effective mapping of habitat fragmentation and ecological corridors (Akumu et al., 2021). They allow the determination of critical parameters, for example, patch cohesiveness, the density of edges, and core area size, which characterize the fragmentation level in landscapes (Berie & Burud, 2018).

AI, especially machine learning algorithms such as CNNs, has compounded habitat classification and fragmentation detection even more (Gu & Zeng, 2023; Wang et al., 2022). Object-Based Image Analysis (OBIA) as a part of image classification helps reduce the subjectivity in habitat mapping and improves the accuracy of the classification due to the large degree of automation (Kasahun & Legesse, 2024). Further, the combination of AI with GIS modelling makes it easier to predict the future fragmentation status and enables conservationists to devise the best approaches to habitat restoration and connectivity.

However, some problems are still encountered while carrying out habitat connectivity assessment, as observed above. Inaccessibility to high-quality GIS data, variation in classification techniques, and the interpretational factors of the AI models are challenges that hamper habitat analysis (Ruiz et al., 2023). Solving these problems necessitates a clearer and systematic method of data integration, the application of Explainable Artificial Intelligence (XAI) methodologies for improved AI interpretability, and close cooperation between ecologists, geospatial specialists, and AI scientists (Macleod et al., 2007).

Narrative synthesis is important for synthesizing articles, especially when a structured, descriptive approach is needed to integrate complex research findings, explore under-researched topics, or when meta-analysis isn't feasible. It allows a reviewer to move beyond simple summaries by critically analyzing and interpreting a body of literature to create a cohesive and persuasive argument (Sukhra, 2022; MD Anderson Cancer Centre and National Institute of Health). While a systematic review often focuses on a narrow question in a specific context, with a prespecified method to synthesize findings from similar studies, a narrative review can include a wide variety of studies and provide an overall summary, with interpretation and critique.

This narrative review synthesizes current advancements in the use of GIS, Remote Sensing, and AI for evaluating habitat connectivity in fragmented landscapes, drawing on more than thirty peer-reviewed articles systematically identified through Emerald, Google Scholar, Elsevier Scopus, and JSTOR databases to ensure comprehensive coverage of recent technological developments and their applications in ecological conservation.

The review aims to evaluate the accuracy and applicability of habitat recognition technologies, explore methods for detecting ecological connectors, and assess the role of geospatial and AI approaches in supporting conservation planning and habitat restoration under the pressures of fragmentation. This narrative review covers literature published between 1988 and 2024, selected through thematic relevance and recent advancements in geospatial and AI – based habitat connectivity analysis.

Geospatial Technologies for Habitat Connectivity Analysis

Habitat fragmentation is one of the most notable threats to the biotic interactions and continues to impede species mobility and change the dynamics of the population. Remote Sensing (RS) and Geographic Information Systems (GIS) provide strong techniques to analyze habitat connectivity. Combining the spatial detailed resolution and the modeling, scientists can determine the changes of the land cover to monitor the connectivity and the possible pathways (Floreano & de Moraes, 2021; Alegbeleye et al., 2024). They apply techniques that enhance the accuracy of the assessment of the habitat fragmentation and the decision-making for its reduction at the detriment of the species biodiversity (Chen et al., 2020).

Remote Sensing Applications in Habitat Connectivity Analysis

Remote Sensing is useful since it offers time series, fine-scale data that is required in the identification of habitat fragmentation and assessment of ecological connectivity. Multispectral and hyperspectral data provided by satellites such as Landsat, Sentinel-2, and MODIS can provide the necessary satellite data of vegetation cover, deforestation, and habitat degradation (Mohd Noor et al., 2018; Guzman et al., 2013). They are valuable in the classification of land cover, which would help the identification of habitat patches, degraded areas, and likely movement pathways of animals.

Other techniques of remote sensing that could be used for habitat connectivity assessments include Unmanned Aerial Vehicles (UAVs), while LiDAR offers more detailed information than satellite imagery due to its ability to penetrate forest canopies and generate high-resolution three-dimensional structural data of vegetation and terrain (Su & Bork, 2006; Pang et al., 2021). UAVs have the advantage of providing near real-time imagery, allowing for the identification of fragmentation at localized scales and within finer spatial resolution (Akumu et al., 2021). LiDAR provides structural information of vegetation cover, density, and terrain that, in turn, affects habitat carrying capacity for different species (Bi et al., 2018). The integration of UAV and LiDAR carries greater detail regarding habitat classification, resulting in a more accurate connectivity model and planning of conservation.

Remote sensing data makes it possible to analyze habitat connectivity across both spatial and temporal scales, enabling the assessment of past fragmentation patterns and the prediction of potential future alterations in habitat connectivity (Chen et al., 2020). Moreover, remote sensing in habitats provides information known as species distribution modeling (SDM), whereby ecology and space variables are used to model habitats based on the occurrence and movement prediction (Kasahun & Legesse, 2024). Incorporation of remote sensing information within other Geographic Information Systems (GIS) databases helps in improving conservation planning and rehabilitation of connectivity in fragmented ecosystems.

GIS-Based Habitat Connectivity Assessment

Spatial analysis for habitat connectivity is made easier by the use of Geographic Information Systems (GIS), which enables spatial data to be processed, analyzed, and presented in the form of networks. GIS analysis allows conservationists to determine how alterations in land-use patterns affect connectivity, where suitable connectivity may be established, and where permeability should be promoted (Prasad & Ramesh, 2019). Connectivity analysis techniques that are commonly used in GIS include the Least Cost Path Analysis (LCPA), which helps in determining the movement corridors of wildlife. Since LCPA takes into consideration landscape resistance factors such as the type of cover, elevation, and human interference, it enables conservation planners to develop wildlife corridors that are least interrupted by barriers (Gidey et al., 2017).

Moreover, Circuit Theory Modeling is more effective for evaluating habitat connectivity than LCPA as it focuses not only on the optimal trace but on the multiplicity of them. Stochastic Random Walk Modelling (SRMM) approximates ecological connectivity across landscapes by treating habitats as conductive rather than applying resistance to movement, allowing the estimation of the probability of species movement between disparate patches (Ruiz et al., 2023). These circuit models are specifically useful in defining circuit connectivity obstacles and developing paths to conserve species with varying movement patterns. Thus, the inclusion of multiple pathways into connectivity assessments improves conservation planning to ensure that corridors provide a buffer to environmental and human interferences.

In addition to spatial analysis, habitat connectivity mapping involving GIS has other quantitative measures, such as the Patch Cohesion Index and Core Area Analysis. The Patch Cohesion Index quantifies how well habitat patches are connected in order to determine if there is still considerable connection for dispersal between fragmented regions (Wang et al., 2022). Core Area Analysis relates to the continuity of the natural habitat within a given landscape, assisting conservation planners in determining whether certain areas within such a landscape are capable of supporting species in the long term. Thus, the linkage of such metrics with remote sensing-derived land cover data offers a GIS-based assessment that provides a complete picture of habitat fragmentation and contributes to evidence-based approaches to conservation practices (Kasahun & Legesse, 2024).

Challenges and Future Directions

There are still limitations in using geographical information system technologies in habitat connectivity assessments. This is mostly due to the unavailability of high-resolution geospatial data that could be attributed to high costs and licenses in owning satellite images and LiDAR datasets, especially in the developing world (Ruiz et al., 2023). Failure to maintain standard approaches to classification, as well as differences in spatial scale, can in sum lead to differences in the models employed for habitat connectivity and thus differences in outcomes in conservation planning. These matters call for further specifications on how to integrate different datasets as well as the improvement of other methods, such as AI-based ones, to step up the accuracy of connectivity assessments.

The next horizons for the field of habitat connectivity research are a seamless integration of AI with GIS and remote sensing. Machine learning methods, including CNNs and OBIA, can help increase the level of accuracy of habitat classification and connectivity assessment (Gu & Zeng, 2023; Wang et al., 2022). Moreover, live connectivity modeling through AI and high-frequency RS data can enhance conservation monitoring by offering timely insights about fragmentation and connectivity status.

Integration of remote sensing with GIS offers unique insights for conservationists to evaluate habitat fragmentation, identify suitable corridors, and support geographic management options, among other applications. Future research should aim at further developing AI methods for improved modeling, acquiring more detailed geographic data, and promoting collaboration between researchers from different fields for better assessment of habitat connectivity. It is possible to conclude that by increasing the efficiency of technological developments and addressing existing issues, geospatial technologies will further help in preserving and rehabilitating ecological connectivity in fragmented habitats.

AI-Driven Approaches for Habitat Connectivity

Artificial Intelligence (AI) has now become significant in the functioning of ecology, especially in mapping and evaluating the connectivity and fragmentation of habitats. The existing literature on habitat loss and connectivity mapping using remote sensors and GIS-based tools has, however, been found to be more time-consuming as these methods require intensive interpretation, and their classification accuracy could be compromised in complex terrains. Deep learning and machine learning models help in these processes by automating classification, increasing precision, and analyzing large amounts of data efficiently. Convolutional Neural Networks (CNNs) enable automated feature extraction and high-accuracy classification by learning complex spatial patterns within satellite imagery, while Object-Based Image Analysis (OBIA) segments imagery into meaningful objects based on spectral and spatial characteristics, allowing for more precise delineation of land cover types and habitat patches. These methods have significantly improved the detection of habitat fragmentation compared to traditional pixel-based classification techniques, which often fail to capture the spatial context required for accurate mapping (Floreano & de Moraes, 2021; Alegbeleye et al., 2024). The combination of AI with GIS helps in examining ecological networks by providing valuable information on habitat connectivity and planning approaches toward the conservation of biologically diverse species.

AI in Habitat Fragmentation Detection

Fragmentation of habitat depends on the classification of land cover as well as detecting changes in land surface features. Using CNNs, situation awareness and prediction of fragmented patches have been made much easier due to the reduced complexity and time efficiency of machine learning models. CNNs process high-resolution satellite imagery, learning spatial features that can distinguish between various habitats, degraded states, and man-made obstructions (Mohd Noor et al., 2018; Guzman et al., 2013). Compared to conventional pixel-based classification techniques, CNNs can detect complex spatial patterns, thereby enhancing the assessment of habitat fragmentation (Herath et al., 2024).

Object-Based Image Analysis (OBIA) enhances classification by segmenting satellite imagery into meaningful objects based on spectral, spatial, and textural characteristics, rather than analyzing individual pixels in isolation. This approach allows for the consideration of shape, size, and contextual relationships between features, resulting in more accurate land cover mapping and habitat patch identification. Compared to pixel-based techniques, OBIA effectively minimizes classification errors and enables more precise differentiation of habitat patches (Akumu et al., 2021). When implemented with deep learning, OBIA can automate habitat fragmentation detection, track land cover changes over time, and evaluate the effects of human interference on ecological networks (Berie & Burud, 2018). Machine learning also facilitates the classification of large areas, making it useful for habitat fragmentation assessments that require rapid and large-scale landscape mapping (Chen et al., 2020).

AI and Ecological Corridor Prediction

In addition to habitat categorization, AI is increasingly used for predicting ecological linkage areas, which serve as pathways between fragmented habitat regions. AI models can predict potential habitat corridors by analyzing vegetation connectivity, land cover, image texture, and background characteristics that indicate strategic pathways for wildlife movement (Kasahun & Legesse, 2024). These models assist conservationists in determining feasible connectivity paths and in assessing the permeability of existing corridors under fragmentation pressures.

Integration of AI with GIS enhances corridor mapping by incorporating Species Distribution Modelling (SDM), Maximum Entropy Modelling (MaxEnt), and terrain analysis into connectivity assessments, thereby improving the identification of potential corridors and suitable habitats (Prasad & Ramesh, 2019). Hybrid AI-GIS frameworks employ predictive modeling to estimate wildlife dispersal distributions and evaluate the efficiency of potential corridors. Combined with AI-based classification outputs, Least Cost Path Analysis and Circuit Theory Models can identify pathways that are optimal in terms of habitat quality, landscape characteristics, and anthropogenic resistance (Gidey et al., 2017). These predictive models assist conservation planners in developing targeted habitat restoration projects and strategies that minimize the impacts of fragmentation.

Future studies should focus on enhancing AI model interpretability, addressing biases in training datasets, and incorporating real-time remote sensing data for efficient connectivity assessments. Applying Explainable AI (XAI) techniques will improve the transparency of methodologies in ecological modeling, ensuring that decisions are based on reliable and interpretable outputs (Ruiz et al., 2023). The application of AI toolsets in habitat connectivity analysis is a promising strategy to ensure the automation, scalability, and precision of fragmentation and ecological network assessments in rapidly changing landscapes.

Challenges in Habitat Connectivity Analysis

There are several challenges observed even with reasonable advancements made in the application of geographical information technology and AI for measuring habitat connectivity. Habitat fragmentation assessments are sensitive to the resolution of available population and land cover data, consistency in classification methods, and the interpretability of machine learning models. Multi-temporal datasets are essential in remote sensing and GIS for measuring landscape connectivity, but challenges such as differing spatial resolutions and limited visibility of high-quality satellite images constrain studies (Floreano & de Moraes, 2021; Alegbeleye et al., 2024). Additionally, controversies exist regarding model interpretability, applicability of results to diverse ecosystems, and data processing time (Mohd Noor et al., 2018). These issues present significant concerns in enhancing the ability to determine habitat connectivity and ensuring the credibility of conservation planning.

Data Availability and Resolution Constraints

One of the main difficulties in performing habitat connectivity analysis is the scarcity of high-resolution remote sensing data. Satellite data are essential for identifying fragmented habitats and monitoring land cover changes; however, acquiring these datasets often involves high costs and licensing restrictions (Guzman et al., 2013). While freely accessible datasets such as Landsat and MODIS provide medium-resolution data, they may not capture finer connectivity structures necessary for detailed habitat assessments (Akumu et al., 2021). In contrast, high-resolution datasets from commercial satellites like WorldView and Pleiades offer detailed imagery but are often prohibitively expensive, particularly for conservation initiatives in developing countries (Berie & Burud, 2018).

Challenges also arise from inconsistencies in spatial and temporal resolutions across datasets, which impact the quality of connectivity models. Missing data due to shadows, poor sensor quality, or irregular collection schedules can hinder accurate classification of habitat patches, affecting the reliability of connectivity assessments (Chen et al., 2020). Furthermore, the lack of uniformity in resolution among datasets complicates integration processes, making it difficult to harmonize classification results for long-term monitoring (Kasahun & Legesse, 2024).

Addressing these challenges calls for the development of open-source remote sensing platforms and efficient methods for integrating multisource data to facilitate more accurate habitat connectivity assessments.

AI Model Interpretability and Reliability

The use of artificial intelligence in habitat connectivity analysis introduces challenges related to model interpretability and generalizability. While deep learning models such as CNNs have achieved high accuracy in habitat classification and fragmentation detection, their decision-making processes remain opaque, complicating ecological validation (Prasad & Ramesh, 2019). This 'black box' nature makes it difficult to understand why certain regions are classified as habitat corridors while others are not (Gidey et al., 2017). Although Explainable AI (XAI) methods are being developed to improve interpretability, their application in ecological modeling is still in its early stages (Ruiz et al., 2023).

Model generalization across different landscapes presents another significant challenge. AI models trained on specific regions may not perform reliably in new environments with different vegetation, climate, or anthropogenic factors (Wang et al., 2022). Given that habitat fragmentation is influenced by diverse ecological and environmental factors, developing AI models that accurately predict fragmentation across varying ecosystems is complex. Approaches such as transfer learning and regional model calibration have been proposed, but their effectiveness depends on the quality of training datasets and computational resources (Kasahun & Legesse, 2024). Ensuring the reliability of AI-driven habitat connectivity assessments will require further development of training methodologies and the establishment of standardized validation procedures across different ecological settings.

Overall, concerns regarding data availability, resolution variability, and model interpretability highlight the critical need for integrating remote sensing, GIS, and AI technologies in habitat connectivity evaluations. Future studies should focus on increasing the availability of high-resolution geospatial data, enhancing AI interpretability, and developing comprehensive algorithms capable of optimizing model performance under diverse ecological conditions. By addressing these challenges, the assessment, communication, and application of habitat connectivity can be strengthened, supporting effective conservation planning and biodiversity management efforts.

Future Research Directions

The integration of AI and GIS for habitat fragmentation analysis has shown promise, but further advancements are needed to improve accuracy, data availability, and the use of ecologically meaningful metrics. Future research should prioritize enhancing AI model interpretability, establishing sustainable geospatial platforms for real-time habitat monitoring, and refining connectivity metrics to better align with conservation needs.

The interpretability of machine learning models remains a major challenge in AI-driven habitat connectivity analysis. Despite deep learning algorithms achieving high accuracy in classifying habitat patches and detecting fragmentation, the decision-making processes of these models often remain unclear to researchers. Continued development of effective Explainable AI (XAI) approaches is essential for enhancing trust in AI models and ensuring their outputs are interpretable and actionable for conservation planning.

Designing open-source data platforms to facilitate real-time monitoring of corridor connectivity presents another critical avenue for future research. High-resolution satellite imagery and geospatial data are often limited in many conservation initiatives, particularly in developing countries. Integrating cloud-based GIS platforms such as Google Earth Engine with Sentinel-2 and MODIS can provide timely and accurate habitat status assessments. Additionally, incorporating citizen science and crowd-sourced ecological data can enrich habitat connectivity models, expanding data availability and spatial coverage.

Improving ecological connectivity measurements is another priority for conservation planning. While current connectivity indices provide useful measures of species dispersal and habitat linkage, they have limitations in capturing the full complexity of habitat connectivity. Future research should explore the use of Graph Theory and Circuit Theory analyses to enhance connectivity assessments, providing more comprehensive evaluations of habitat networks and potential corridors.

By addressing these research directions, the integration of AI, GIS, and remote sensing in habitat connectivity analysis can be optimized, enabling more accurate, scalable, and ecologically meaningful conservation strategies in the face of rapid environmental change.

Conclusion

The integration of Geographic Information Systems (GIS), Remote Sensing, and Artificial Intelligence (AI) has significantly enhanced the evaluation of habitat connectivity in fragmented environments. These technologies provide essential tools for mapping environmental patterns, detecting fragmentation, and identifying ecological connectivity corridors that support species mobility and conservation (Floreano & de Moraes, 2021; Alegbeleye et al., 2024). Utilizing high-resolution satellite imagery, UAV-based data collection methods, and AI-driven classification guidelines enables researchers to improve habitat identification and overall habitat management (Mohd Noor et al., 2018; Guzman et al., 2013). Spatial modeling analyses within GIS frameworks, such as Least-Cost Path Analysis (LCPA) and Circuit Theory Modeling, further support conservation measures by estimating connectivity lengths and informing habitat restoration strategies (Prasad & Ramesh, 2019).

Despite these advancements, several challenges remain unaddressed in habitat connectivity analysis. Issues such as the limited availability of high-resolution geospatial data, inconsistencies in deforestation classification approaches, and the interpretability of AI-based models continue to hinder standardized and effective connectivity assessments (Ruiz et al., 2023). Addressing these challenges will require interdisciplinary collaboration, the expansion of open-source remote sensing platforms, and the optimization of AI algorithms to enhance the accuracy and quality of ecological modeling (Kasahun & Legesse, 2024). The integration of Explainable AI (XAI) techniques with geospatial analysis offers the potential to improve transparency and predictive capabilities in assessing habitat fragmentation dynamics (Gidey et al., 2017).

Future research should prioritize the development of open-access geospatial data portals to facilitate real-time monitoring of habitat connectivity, the refinement of ecological modeling approaches to accommodate multi-species mobility frameworks, and the incorporation of AI to optimize classification accuracy and connectivity estimation (Chen et al., 2020). As environmental pressures on natural ecosystems continue to intensify, conservation efforts by stakeholders will increasingly depend on the application of big data analytics for effective planning and management.

The integration of GIS, Remote Sensing, and AI not only addresses current gaps in habitat connectivity research but also offers scalable and adaptable tools for biodiversity conservation planning. Moving forward, habitat connectivity research should adopt innovative approaches and emerging technologies, including advanced AI methods, GIS analyses, and ecological modeling, to develop coherent, efficient, and impactful conservation policies that support the preservation of biodiversity in rapidly changing landscapes.

References

Akumu, C. E., McLaughlin, D., & Mitishita, E. (2021). Evaluating the effectiveness of UAV and LiDAR technologies in habitat connectivity assessments. Remote Sensing in Ecology and Conservation, 7(2), 134–148.

Alegbeleye, B. O., Green, S., & Martin, L. J. (2024). Assessing biodiversity loss due to land-use change: The role of geospatial analytics. Journal of Environmental Management, 325, 116243.

Anderson, S. H., Jenkins, C. N., & Stouffer, P. C. (2020). Forest fragmentation and its impact on species movement. Biological Conservation, 248, 108673.

Berie, G., & Burud, I. (2018). LiDAR applications in forest and habitat connectivity mapping. International Journal of Remote Sensing, 39(6), 2027–2045.

Chen, X., Zhang, H., & Li, P. (2020). Advances in remote sensing for habitat fragmentation monitoring: A review. Ecological Indicators, 113, 106242.

Dunning, J. B., Danielson, B. J., & Pulliam, H. R. (1992). Ecological processes that affect populations in complex landscapes. Oikos, 65(1), 169–175.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics, 34, 487–515.

Floreano, D., & de Moraes, A. (2021). Remote sensing applications for biodiversity conservation and landscape connectivity. Landscape Ecology, 36(4), 857–873.

Forman, R. T. T., & Alexander, L. E. (1998). Roads and their major ecological effects. Annual Review of Ecology and Systematics, 29, 207–231.

Gidey, M., Fekadu, G., & Bekele, T. (2017). Landscape fragmentation and its implications on wildlife connectivity: A GIS-based analysis. African Journal of Ecology, 55(3), 421–432.

Gu, J., & Zeng, Y. (2023). Deep learning for habitat classification: A case study using CNNs and OBIA. Journal of Geospatial Science, 12(1), 45–61.

Guzman, Q., Martinez, D., & Roberts, M. (2013). The role of MODIS and Landsat imagery in habitat connectivity assessments. Environmental Monitoring and Assessment.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., … & Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on biodiversity. Science Advances, 1(2), e1500052.

Hanski, I. (1998). Metapopulation dynamics. Nature, 396(6706), 41–49.

Herath, H. M. B. S., Nayanajith, J., & Jayasinghe, K. D. P. P. (2024). Geospatial and AI-based modelling to assess temporal and spatial dynamics of forest fragmentation. Proceedings of the Asian Conference on Remote Sensing (ACRS 2024).

Kasahun, B., & Legesse, M. (2024). Integrating machine learning with GIS for ecological connectivity analysis. Remote Sensing Applications: Society and Environment, 27, 100843.

Laurance, W. F., Croes, B. M., Tchignoumba, L., Lahm, S. A., Alonso, A., Lee, M. E., … & Ondzeano, C. (2006). Impacts of roads and hunting on Central African rainforest mammals. Conservation Biology, 20(4), 1251–1261.

Li, X., & Demir, K. (2023). Predicting habitat fragmentation using AI-driven geospatial models. Ecological Informatics, 68, 101762.

Macleod, R., Nagendra, H., & Coomes, D. (2007). Standardizing methods for habitat connectivity assessments: Challenges and recommendations. Conservation Biology, 21(5), 1261–1272.

McGarigal, K., & Cushman, S. A. (2002). Comparative evaluation of experimental approaches to the study of habitat fragmentation effects. Ecological Applications, 12(2), 335–345.

MD Anderson Cancer Center, The University of Texas, Research Medical Library. (Year – not mentioned)

Mohd Noor, S., Hashim, M., & Mat, J. (2018). UAV-based habitat monitoring for biodiversity conservation. Journal of Applied Remote Sensing, 12(3), 032006.

Noss, R. F., & Daly, K. M. (2006). Incorporating connectivity into conservation planning. Conservation Biology, 20(6), 1675–1685.

O'Neill, R. V., Krummel, J. R., Gardner, R. H., Sugihara, G., Jackson, B., & DeAngelis, D. L. (1988). Indices of landscape pattern. Landscape Ecology, 1(3), 153–162.

Opdam, P., & Wascher, D. (2004). Climate change meets habitat fragmentation: Linking landscape and biogeographical scale levels in research and conservation. Biological Conservation, 117(3), 285–297.

Prasad, S., & Ramesh, T. (2019). Least-cost path analysis for ecological corridor design: A GIS-based approach. Environmental Conservation, 46(2), 119–128.

Ruiz, C., Moreno, J., & Wang, Y. (2023). Explainable AI in ecological modeling: Addressing the black box problem. AI in Ecology, 9(1), 22–37.

Saunders, D. A., Hobbs, R. J., & Margules, C. R. (1991). Biological consequences of ecosystem fragmentation: A review. Conservation Biology, 5(1), 18–32.

Schumaker, N. H. (1996). Using landscape indices to predict habitat connectivity. Ecological Applications, 6(2), 555–565.

Sukhera J. Narrative Reviews: Flexible, Rigorous, and Practical. J Grad Med Educ. 2022 Aug;14(4):414-417. doi: 10.4300/JGME-D-22-00480.1. PMID: 35991099; PMCID: PMC9380636.

Taylor, P. D., Fahrig, L., Henein, K., & Merriam, G. (1993). Connectivity is a vital element of landscape structure. Oikos, 68(3), 571–573.

Tilman, D., & Lehman, C. (1997). Habitat destruction and species extinctions. Ecological Applications, 7(3), 1090–1101.

Turner, M. G., Gardner, R. H., & O'Neill, R. V. (2001). Landscape ecology in theory and practice. Springer-Verlag.

Urban, D., & Keitt, T. (2001). Landscape connectivity: A graph-theoretic perspective. Ecology, 82(5), 1205–1218.

Wang, T., Liu, X., & Chen, R. (2022). Patch cohesion index as a measure of habitat fragmentation: Applications and limitations. Landscape and Urban Planning, 221, 104338.