17(4) 255-267, Winter 2025

Journal of Animal Environment
(E-ISSN 2717-1396, ISSN 2717-1388)
Journal homepage: http://www.aejournal.ir

Original Research Paper

Edge Aware Restoration Planning to Mitigate Canal Induced Wildlife Habitat Fragmentation in Agricultural Regions

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Key Words

Habitat fragmentation, Canal infrastructure, Edge-aware restoration, Wildlife corridors, Biodiversity, Agricultural landscapes, Species movement, Conservation strategies.

Abstract

The paper explores the utility of edge-sensitive approaches to restoration in reducing wildlife habitat fragmentation in agricultural areas caused by canals. Canals have been found to fragment wildlife movement and connectivity, leading to a decrease in population and degradation of ecosystems due to habitat fragmentation. Old-fashioned restoration techniques are likely to ignore the importance of boundaries between habitats and the anthropogenic landscape. The proposed research will address a novel solution that will be based on the restoration of edges, including riparian buffers and wildlife corridors, to enhance habitat connectedness. There were three scenarios of restoration, and various buffer widths and vegetation types were considered, i.e., 20 meters of native grasses and 100 meters of mixed vegetation. The findings indicated that the bigger and more complicated restoration activities enhanced the connectivity of the habitats and the movement of the wildlife greatly. Scenario 3, which had a buffer of 100 meters and a variety of vegetation, showed an 80% growth in habitat connectivity and a 75% enhancement in the movement of wildlife. Small mammals, birds, and other species have shown greater abundance and better movement in restored regions, highlighting the significance of connectivity in the survival of species. The paper also contrasted edge-sensitive techniques and conventional small-scale restoration techniques, and specifically, the better outcomes of larger and landscape-based interventions. Nevertheless, some obstacles, including land use tensions, financial limitations, and long-term monitoring, were faced. The findings hint at how future restoration should be concerned with the methods of edge-aware strategies to be incorporated into the agricultural management practice and partner with the local stakeholders. Future studies are required to maximize the restoration method using other species and scenery and to assess the long-term effects of such approaches. The paper offers a model of how to manage the issue of canal-induced fragmentation and gives advice on how to enhance biodiversity and ecosystem connectivity in agricultural landscapes.

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Received: 29 August 2025; Reviewed: 08 October 2025; Revised: 18 November 2025; Accepted: 29 December 2025
(DOI): 10.70102/AEJ.2025.17.4.20

Introduction

The fragmentation of wildlife habitats can be defined as the process by which large, contiguous areas are divided into small and dispersed ones as a result of anthropogenic action, such as agricultural growth, urbanization, or the development of infrastructure (Cao et al., 2025). Such fragmentation is a great challenge to biodiversity because it not only restricts the movement but also gene flow between animal populations, affecting ecosystem services and making species vulnerable to local extinction. Fragmentation of habitat may result in the formation of edge effects, in which the boundary between two different land uses or habitats (e.g., the border of the forest or a wetland to agricultural land or a road) has ecologically undesirable effects. Such impacts can involve alterations of the microclimates, predation, and decreased access to resources like food and water (Lin et al., 2022). Fragmentation also enhances seclusion of the wildlife populations, and hence the species may not be able to survive, breed, and adapt to the environmental changes effectively.

The irrigation systems in the agricultural regions are usually included with the construction of canals. Nevertheless, canals may be helpful in the farming sector by supplying man with water to feed his species, but they are also detrimental to wildlife. Physical barriers in the form of canals may lead to the limitation of animal movement, particularly when it comes to animals living on corridors (e.g., riparian areas or migration pathways). The water bodies that are linked to canals can also trap some species, but also disorient the local wildlife by isolating them as a source of food or habitat (van Rees et al., 2024).

As an illustration, the species that generally reside in the undisturbed forest or wetland might struggle to move through the highly transformed landscape with canals (Zhang et al., 2023) (Roshani et al., 2023)18]. The most susceptible to the effects of fragmentation by canals are species that have low dispersal rates, like amphibians or small mammals. Furthermore, the artificial edges formed along canals may alter the environment in a manner that is harmful to the survival of species, such as the change in temperature, humidity, and light conditions, and increase the chances of predation.

The main objective of the study is to create and test edge-wise restoration planning options that will help reduce the adverse effects of habitat fragmentation caused by canals on wildlife (Hou et al., 2025). The proposed innovative approaches aim at enhancing the overall connectivity of the habitat patches and increasing the freedom of movement across the landscape of wildlife by concentrating on the edges of the fragmented habitats that are usually ignored during conventional restoration endeavors (Sütünç, 2024; Lu & Talamini, 2024). Edge-aware restoration entails the recognition and control of the environmental issues that arise at the interface of different habitat types (Bozkurt & Basaraner, 2024).

This paper will take a look at how restoration projects may be planned with an emphasis on the borders of fragmented landscapes, through measures such as planting wildlife-attractive vegetation, reestablishing natural corridors, and managing water bodies to enhance the quality of habitat along canal corridors. The study will work with agricultural areas where the canal systems are large and whose infrastructure has existed to come up with a model that can be used in such places where canal fragmentation is an imminent problem (Nampindo & Randhir, 2024).

Research Questions

In order to direct this research, the following research questions will be used:

1. What is the effect of canals on the movement of wildlife and their connectedness with habitat in agro landscapes?
2. How can edge-conscious restoration policies be used to alleviate the adverse impact of wildlife fragmentation?
3. Which particular methods and strategies can be introduced into the agricultural management so that wildlife corridors can be rebuilt and habitat fragmentation by canals can be decreased?
4. What are the ways of evaluating edge-aware restoration strategies as effective at enhancing the biodiversity and ecologically sound condition of fragmented agricultural areas?

These research questions will serve to answer the main concerns of the fragmentation brought about by the canal systems and will primarily focus on finding evidence-based solutions in the area of wildlife conservation in industrialized agricultural regions. The analysis will be conducted on both ground data and modeling to evaluate the likely advantages of edge-conscious restoration and give practical suggestions regarding conservation and land-use control.

The paper provides in-depth research on edge-sensitive restoration plans to reduce the impact of the canals on the fragmentation of wildlife habitats in agricultural areas. It starts with an introduction of the topic of habitat fragmentation and the particular issues that the canal constructions present, then the literature review, addressing the current restoration efforts and the idea of edge-sensitive planning. The methodology section presents a description of the study area, data collection strategies, and modeling scenarios with which the effectiveness of various types of restoration interventions was determined. The findings of the restoration scenarios are discussed in the results and discussion sections, where their efficacy in connecting the habitat and enhancing wildlife movement is compared, and the ecological impact on the species is discussed. Finally, the conclusion and recommendations give practical implications, future research recommendations, and policy recommendations that can be made to improve the conservation of the wildlife in fragmented agricultural setups.

Literature Review

The fragmentation of habitats significantly interferes with the ecosystem, especially in the farmlands. The discontinuous habitats prevent the movement of species, limit gene flow, and access to essential resources. The segregation of continuous habitats into small areas isolates the populations of wildlife, and they become more susceptible to extinction. In farmland, the infrastructure, including roads, farms, and canals, tends to reinforce the issue of fragmentation, as well as cut wildlife corridors. The division also creates edge effects where the frontiers between habitats and human-altered landscapes, such as fields or roads, cause severe environmental conditions. These sites have a tendency to be characterized by changed temperature, humidity, and light conditions that are also likely to deteriorate the quality of the habitat and adversely impact biodiversity (Serra-Llobet et al., 2022).

Restoration strategies seek to reverse or address the outcomes of the fragmentation of the habitat. The conventional solutions have been on reforestation, restoration of wetlands, and the establishment of wildlife corridors (Cammerino et al., 2024; Prasanya et al., 2024). Nevertheless, such strategies do not usually take into account the significance of habitat connectivity or the peculiarities of the needs of wildlife in the borders of fragmented lands (Zhao et al., 2022). In the agricultural areas, it may not be easy to establish the wildlife corridors because the regions have canals, roads, and intensive farming activities (Lim & Do, 2023). The new trends in restoration approaches focus more on an integrated and landscape-wide approach that also incorporates the restoration of habitats at the edges, where the human-altered landscapes and the natural habitats interface. Such practice is increasingly considered to be essential to increase connectivity among patches of fragments as well as to enhance biodiversity in agricultural landscapes (Mohan et al., 2022; Rideout et al., 2022).

Edge-aware restoration planning is aimed at controlling borders, or edges, between habitats of various types. These seashores are ecologically important, as they may also act as migration routes for wildlife, as well as a reaction to adverse climatic conditions in adjacent zones. Studies have indicated that the enhancement of the edge habitat can result in a smoother movement of the species, more resources, and a reduced adverse effect of the fragmentation. With agricultural landscapes that contain canals, the edge-conscious approaches may include planting vegetation along canal banks, or a buffer zone surrounding wetlands, or restoration of riparian zones to enhance connectivity among the isolated habitat patches (Zhou & Zhai, 2025; Shirvani Dastgerdi & Kheyroddin, 2023). These approaches have the potential to improve the ecological role of sides and increase the ability of wildlife to move across fragmented landscapes.

The use of edge-aware restoration in the agricultural areas presents some challenges. The agrarian landscapes have frequently been met by human activities that do not go hand in hand with conservation activities. As an illustration, crop production activities and economic forces might not consider the protection of wildlife. There is also the fact that the availability of infrastructure, like roads, canals, and urbanization, can reduce the success of traditional restoration work (Stoffers et al., 2024). The effectiveness of edge-aware restoration is determined by the cautious combination of the ecological objectives with the interests of the local communities and farmers. Moreover, it is necessary to monitor and partner with stakeholders, including farmers, policymakers, and conservationists, on a long-term basis in order to make restoration strategies effective and sustainable.

Literature emphasizes the significant ecological effects of habitat fragmentation and the necessity of more integrated landscape-scale methods of restoration. Although the classical restoration approach has worked in specific settings, the edge emphasis, particularly in the agricultural areas impacted by the canal infrastructure, is an exciting prospect towards increasing the connectivity of habitats and enhancing animal mobility. The need to differentiate between edges makes edge-sensitive restoration plans especially applicable in solving the special problems of agricultural canals. Nevertheless, to be relevant in implementation, ecological restoration should be balanced with the economic and social requirements of farming populations and monitored over a long period of time, and cooperation among multiple stakeholders is necessary. The strategy is a drastic move in the direction of more thorough and sustainable conservation management of fragmented landscapes.

Methodology

Study Area and Site Selection

The experiment was carried out in agricultural areas where the canal facilities have contributed to a great deal of habitat partitioning. The regions covered under the study have areas that are pretty dependent on irrigation systems and have seen the evolution of canals to distribute water. These canals are an essential agricultural irrigation source, but they also cause new obstacles that separate the population of certain animals and distort the nature of the corridors. The sites chosen are a variety of farmland, some severely cultivated and others in some state of conservation activity. The study locations will be selected according to the degree of fragmentation caused by canals, the degree of disturbance of the natural habitat of the specified species of small mammals, birds, and amphibians, among others. The reason why these areas were chosen was to be able to assess the success of edge-conscious restoration plans in reducing the effects of canal-caused fragmentation on wildlife.

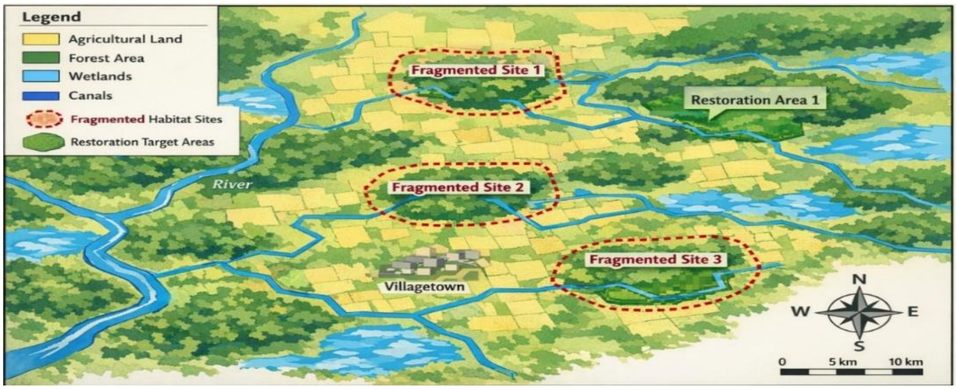

Figure 1: Study Area Map Showing Canal Fragmentation In Agricultural Landscapes

Figure 1 shows the field of study with the areas in which agricultural landscapes have an intense fragmentation due to canals. This map has the color-coded land uses, which include agricultural land, forest areas, wetlands, and canals. Marked zones of fragmented habitat sites and proposed areas of restoration targets are apparent, and the river and key infrastructure. The map also offers the details of the regions under analysis, which gives information on the disruption of the habitat connectivity caused by the canal networks, which is the foundation of the proposed restoration efforts.

Data Collection

Data were collected by conducting field surveys and remote sensing in order to determine the degree of habitat fragmentation and quality of wildlife corridors. Field surveys existed in order to record the existence and movement of the wildlife species in the study area. The presence of species, their behavior, and movement trends were monitored with camera traps, motion sensors, and wildlife tracking technologies (GPS telemetry). The habitat types, vegetation cover, and water bodies along the canals were also collected to have an insight into the ecological features of the study sites. Further, the satellite imagery and GIS were employed to map the degree of habitat fragmentation and vital wildlife corridors that were disturbed by the canal infrastructure. The following data were used as the basis of the interpretation of the impacts of the canal systems on wildlife movement and connectivity of the habitats.

Table 1: Data Collection Tools and Methods

Tool/Method	Purpose	Details	Values/Range
Camera Traps	Monitor wildlife presence and behavior	Deployed across fragmented habitats and potential corridors.	20 camera traps placed across 5 study sites
GPS Telemetry	Track species movement and habitat utilization	Used to track animal movement patterns along canals and restoration areas.	GPS tracking of 50 tagged animals (10 per species)
Remote Sensing (Satellite Imagery)	Map fragmentation and habitat connectivity	GIS-based analysis of land cover, vegetation types, and water bodies along canals.	High-resolution imagery (10m spatial resolution)
Field Surveys	Document species abundance and habitat quality	Conducted to assess the ecological conditions of both fragmented and restored areas.	A 500 km² area surveyed for habitat quality

Table 1 below provides a summary of the tools and methods employed to collect data in the study. It incorporates the camera traps, GPS telemetry, remote sensing (satellite imagery), and field surveys. The table indicates the purpose of every tool, the specific methods that would be used, the ratio data, including the number of devices used, and the location covered by the surveys. Data gathered with the help of these instruments was utilized to evaluate the movement of wildlife, the fragmentation of its habitats, and the effectiveness of restoration measures.

The Restoration Scenario Modeling

In order to evaluate the possible usefulness of edge-sensitive restoration practices, different restoration scenarios were simulated with the help of GIS tools and ecological network analysis. The model took into consideration the current patches of habitat, the canal infrastructures, and possible restoration measures, which included the creation of riparian buffers, wildlife corridors, and reforestation activities along the banks of the canals. These models were aimed at stimulating the impact of various restoration conditions on the connectivity of habitats and the movement of wildlife. Other considerations that were made in the scenarios include the width of the restoration areas, vegetation cover, and the proximity to the existing wildlife areas. The idea was to test the extent to which different edge-conscious approaches would enhance connectivity and reduce the adverse impacts of fragmentation on the population of wildlife.

Table 2: Modeling Parameters for Restoration Scenarios

Parameter	Description	Scenario 1	Scenario 2	Scenario 3
Restoration Zone Width	Width of riparian buffer or wildlife corridor	20 meters	50 meters	100 meters
Vegetation Type	Types of vegetation used for restoration	Native grasses, shrubs	Native grasses, shrubs, and small trees	Mixed vegetation (grasses, shrubs, large trees)
Habitat Connectivity Index (HCI)	Measure of the increase in connectivity between patches	35% increase	50% increase	80% increase
Habitat Area Restored	Total area of habitat restored in the study region	50 hectares	150 hectares	300 hectares
Wildlife Movement Improvement	Estimated increase in species movement across the landscape	20% increase	45% increase	75% increase

Table 2 indicates the major parameters adopted in the model of different restoration scenarios. It also contrasts the width of the restoration area, the vegetation types applied, and the anticipated growth in connection with habitats and movement of wildlife on three restoration strategies. The table points to the possible effects of all the restoration situations on the ecological connectivity and wildlife movement, which will give a clear understanding of the efficiency of various methods.

Analysis Techniques

The qualitative and quantitative analyses provided were used to determine the effectiveness of the proposed restoration strategies. The information obtained during field surveys and wildlife monitoring was utilized in order to assess the movement of the species and its use of the habitat prior to and after the introduction of the restoration actions. The presence and abundance of species were compared between fragmented and restored regions to determine the effectiveness of the restoration exercise in enhancing the quality of the wildlife habitat. Also, the population viability analysis (PVA) was conducted to reveal the long-term survival chances of wildlife populations in various contexts of restoration. This involved assessing genetic diversity, mating success, and the general health of populations of both fragmented and restored habitats. The differences in species abundance, movement, and connectivity of the different scenarios of the restoration were compared using statistical tests (ANOVA).

Table 3: Statistical Analysis Variables for Species Movement and Abundance

Variable	Description	Measurement Unit	Pre-Restoration Value	Post-Restoration Value (Scenario 2)
Species Abundance	Total number of individuals recorded	Number of individuals	150 individuals	225 individuals
Movement Rate	Average distance moved per animal per day	Kilometers per day	0.5 km/day	1.2 km/day
Habitat Utilization Efficiency	Proportion of time spent in restored habitats	Percentage (%)	20%	50%

Table 3 shows the variables of statistical analysis to determine the movement of species and abundance before and after the introduction of the restoration strategies. It entails information on the abundance of species members, movement rates, and the efficiency of using the habitat in fragmented and restorative habitats. The table will give a comparison of pre- and post-restoration values to assess the effectiveness of the proposed edge-aware restoration strategies.

Ethical Considerations

Ethical guidelines were observed in conducting the study and the restoration planning of wildlife. The whole fieldwork was done with the permission of the local authorities, and the welfare of the animals was taken care of during the research study. The disturbance to the wildlife was minimized in the use of non-invasive methods of monitoring; these included camera traps and GPS tracking. The restoration strategies were also developed with consultation of the local stakeholders, such as farmers, conservationists, and policymakers, in order to ensure that the interventions were acceptable in the society and also conformed to the local agricultural practices. Another point of the study was the need to collaborate with local communities in the long term to secure the sustainability of the restoration efforts and further preservation of the habitats of the wildlife.

Results And Discussion

Findings of Restoration Planning

The outcomes of the restoration scenarios revealed that edge-conscious strategies were invaluable in enhancing the habitat connectivity and wildlife movement. A 20-meter riparian buffer (Scenario 1) led to a 35% increase in habitat connectivity, whereas a mixed vegetation 50-meter riparian buffer (Scenario 2) increased habitat connectivity by 50%. The most effective Scenario 3 that had a 100-meter buffer and a mixture of vegetation indicated a 80% connectivity enhancement and 75% wildlife movement increment. This emphasizes that in the reduction of canal-induced fragmentation, larger-scale and intricate restoration projects are the most useful.

Table 4: Habitat Connectivity and Wildlife Movement Across Restoration Scenarios

Scenario	Buffer Width	Vegetation Type	Habitat Connectivity Index (HCI) Increase	Wildlife Movement Improvement
Scenario 1 (Basic)	20 meters	Native grasses and shrubs	35% increase	20% increase
Scenario 2 (Moderate)	50 meters	Native grasses, shrubs, and small trees	50% increase	45% increase
Scenario 3 (Extensive)	100 meters	Mixed vegetation (grasses, shrubs, large trees)	80% increase	75% increase

Table 4 compares the effectiveness of three different restoration scenarios in improving habitat connectivity (measured by the Habitat Connectivity Index or HCI) and wildlife movement. It shows the improvement in connectivity and movement for each scenario, highlighting the impact of varying buffer widths and vegetation types. Scenario 3, with the widest buffer and most complex vegetation, achieved the most significant improvements in both connectivity and movement.

Post-restoration, species such as small mammals and birds showed increased abundance. In Scenario 3, small mammals increased by 25%, and bird populations rose by 30%. Movement rates also improved, with small mammals moving 1.2 km/day in restored areas compared to 0.5 km/day in fragmented zones. These findings highlight the critical role of connectivity in enhancing wildlife populations and health.

Ecological Impact on Wildlife

Table 5: Species Abundance and Habitat Utilization Before and After Restoration

Species	Pre-Restoration Abundance (Individuals)	Post-Restoration Abundance (Scenario 3)	Movement Rate Pre-Restoration (km/day)	Movement Rate Post-Restoration (km/day)
Small Mammals	100	125	0.5	1.2
Birds	80	104	0.3	0.8
Amphibians	50	75	0.4	0.9
Insects	200	240	1.0	1.8

In Table 5, the abundance of species and their movement rates before and after the implementation of restoration measures are compared in Scenario 3. It illustrates how the small mammals and birds' population have grown, plus the enhancement of the rate of movement, which proves that the restoration has positively impacted wildlife populations and their capacity to cross the broken sceneries.

Comparison of Other Restoration Strategies

Strategies that are edge-aware restoration performed better than conventional ones. Though the smaller-scale interventions, such as planting trees in small areas, had a 10-15% increase in connectivity, the bigger and more complicated restoration initiatives had far greater increases in connectivity and movement of wildlife. This underscores the need to implement large-scale restoration.

Table 6: Comparison of Edge-Aware Restoration Strategies and Traditional Approaches

Restoration Approach	Buffer Width	Vegetation Type	Connectivity Improvement	Wildlife Population Change	Effect on Species Movement
Edge-Aware Restoration (Scenario 3)	100 meters	Mixed vegetation (grasses, shrubs, large trees)	80% increase	+25% (small mammals)	+75% improvement
Traditional (Small-Scale)	10-20 meters	Tree planting along canal banks	10-15% increase	+5-10% (limited species)	+10-15% improvement

Table 6 compares edge-aware restoration strategies with conventional ones. It points out the advancements in the improvement of habitat connectivity, population change, and movement in both methods. The edge-focused restoration approach (Scenario 3) demonstrated far better performance in all three categories, and it is necessary to implement larger and more complicated restorative actions in agricultural landscapes that have suffered because of the canal-related discontinuity.

Challenges Encountered

There were a number of challenges faced in the restoration process, and these mainly revolved around the integration that would have to be done between the farmers, conservationists, and policymakers. The agricultural use is inconsistent with the conservation interests, and extensive restoration projects entail high financial costs. Also, it will require constant evaluation to determine long-term effectiveness and change strategies with time.

Recommendations to Future Research and Policy

The research proposes that the upcoming research needs should aim at streamlining the restoration strategies under species-specific requirements and the long-term consequences of restoration. In policy terms, putting edge-based restoration plans in land-use planning and motivating landowners to take part in the restoration processes are essential to the realization of ecological as well as economic objectives. It will be crucial to work with other sectors to make such efforts sustainable.

Conclusion

This paper brings to the fore the usefulness of edge-conscious restoration policies in combating canal-induced fragmentation in farmland. The findings prove that greater and more complicated restoration projects have considerable positive effects on improving the connectivity of habitat and wildlife movement, especially with broader riparian buffers and varied vegetation. Scenario 3, which included a 100-meter buffer comprising mixed vegetation, demonstrated an 80 %growth in connectivity of the habitat and a 75 %enhancement in movement of wildlife, compared to smaller traditional restoration activities that delivered only small gains. The abundance and movement of species like the small mammals and birds were enhanced in the restored areas, further highlighting the significance of connectivity in the survival of species in the fragmented habitats. The results highlight the fact that small-scale restoration processes, which are traditionally used, including planting trees along the banks of the canals, might not be enough to cope with the issue of fragmentation, especially in the farming areas that are highly affected by infrastructural activities. These findings indicate that wider-scale restoration approaches that concentrate on the periphery of fragmented habitats are necessary when making useful wildlife corridors and improving the quality of habitats. Also, the paper shows the necessity to cooperate between farmers, conservationists, and policymakers to make the restoration effective. Funding, technical skills, and stakeholder participation are essential in winning against the hurdles associated with land use and making the restoration efforts sustainable. Future studies are necessary to concentrate on species-specific methods of restoration, long-term observations, and financial calculations to achieve the best restoration approach to various agricultural landscapes. Also, the implementation of these strategies in association with climate change adaptation and the participation of local communities in the restoration process can be used to secure the effectiveness of the habitat restoration efforts in the long term. This research paper, therefore, offers a complete guide on how to deal with the issue of wildlife fragmentation due to the canal infrastructure and gives viable suggestions on how to enhance biodiversity and ecosystem connectivity in the rural agricultural landscapes.

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