



## Perspective

# Ecological Peace Corridors: A new conservation strategy to protect human and biological diversity

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## ABSTRACT

In a highly anthropized world with increasing human conflicts and a global call for expanding both protected and indigenous areas, we must reevaluate the importance of corridors. Here I propose a new conservation tool, called Ecological Peace Corridors (EPCs), as crucial for preserving biodiversity and encouraging peacekeeping. These corridors can facilitate wildlife movement and genetic exchange, counteracting the fragmentation caused by human activities. The importance of EPCs will grow as habitat fragmentation increases, highlighting the need for proactive conservation strategies and sustainable land-use planning. The 30 × 30 initiative aims to expand protected areas but to reach its full potential, it must be paired with rewilding and land-sharing strategies. Rewilding restores ecosystems to their natural states, enhancing ecological processes and resilience, while land sharing integrates conservation into human-dominated landscapes, promoting coexistence and connectivity. Buffer zones, part of the EPC framework, reduce conflicts by providing neutral spaces, thus enhancing safety for humans and wildlife. These efforts boost habitat connectivity, genetic diversity, and ecosystem resilience, aligning with global conservation goals. EPCs, by promoting biodiversity preservation and geopolitical stability, offer a solution to challenges like biodiversity loss, climate change, and human conflict. Their successful implementation requires international cooperation, long-term planning, and a commitment to both ecological and human well-being. A methodology for identifying EPCs is here proposed and includes the use of AI-ML for land cover classification, gap analysis to identify priority areas, and Least Cost Path (LCP) analysis to optimize corridor routes by balancing ecological needs with social considerations. The Italian zonation system of National Parks is suggested as a model for planning EPCs, balancing conservation and human needs. Therefore, EPCs can address environmental and geopolitical challenges in conflict zones by removing military infrastructures, restoring vegetation, establishing patrolled corridors, fostering biodiversity conservation and peacebuilding. This approach not only benefits ecosystems and wildlife but also promotes cooperation and trust among neighbouring countries, paving the way for sustainable peace in conflict-affected areas.

Nature knows no boundaries.  
What human beings divide,  
all other living beings unite.

## 1. Introduction

### 1.1. The underestimated importance of corridors in our lives

Corridors are often overlooked although they are vital elements in the design and functionality of various environments, including houses, buildings, hospitals, conference venues, and towns. They serve as crucial

arteries that facilitate movement, enhance accessibility, and contribute to the safety and efficiency of spaces.

Urban design emphasizes the importance of corridors, particularly in the form of streets and pedestrian pathways. These corridors are essential for the connectivity of different parts of a town or city, promoting accessibility and mobility. Well-planned urban corridors can enhance the quality of life for residents by providing safe and efficient routes for walking, cycling, and public transportation. They can also foster economic activity by connecting commercial areas with residential neighbourhoods (Gehl, 2010).

In residential homes, corridors are essential for connecting different rooms and creating a coherent flow throughout the house. They provide

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a means of easy and organized access to various parts of the home, promoting convenience and privacy. A well-designed corridor can also enhance the aesthetic appeal of a home, serving as a canvas for decorative elements such as artwork, lighting, and architectural features (Ching, 2014). In commercial buildings and offices, corridors are critical for the efficient movement of people. They help in managing the flow of employees and visitors, reducing congestion and enhancing productivity. Corridors in office settings often incorporate elements that encourage collaboration and interaction among employees, such as breakout areas and informal meeting spaces. Moreover, they play a significant role in emergency evacuation plans, providing clear and accessible routes to safety (Preiser, 2018). Hospitals and healthcare facilities place even greater importance on the design of corridors. These spaces must accommodate a high volume of traffic, including patients, healthcare workers, and medical equipment. Well-designed hospital corridors ensure smooth and swift transportation of patients, which is crucial for timely medical intervention. Additionally, they must adhere to strict hygiene standards and provide sufficient space for equipment and emergency procedures (Ulrich et al., 2008). Studies have shown that the design of hospital corridors can significantly impact the efficiency of healthcare delivery and patient outcomes (Lawson and Phiri, 2003). In the context of conferences and large events, corridors serve as vital conduits for the movement of attendees. They help in organizing the flow of people between different sessions, exhibition areas, and social spaces. Effective corridor design can enhance the overall experience of the event, providing clear signage, ample space, and opportunities for networking and informal interactions (Event Design Handbook, 2016).

Corridors, therefore, are not merely transitional spaces; they are fundamental to the functionality, safety, and aesthetic appeal of various environments. Their design and maintenance have far-reaching implications for the efficiency and well-being of users, whether in a home, office, hospital, conference, or urban setting. Recognizing their importance and investing in thoughtful corridor design can lead to improved outcomes in both private and public spaces.

Although corridors are never mentioned in the specifications of estate advertisements, illustrating how poorly recognised by our society they are, corridors can actually save lives. In fact, corridors play a crucial role in peacekeeping during war and conflicts, serving as essential routes for the movement of humanitarian aid, the safe passage of civilians, and the facilitation of negotiations (Ambrosini and Schnyder von Wartensee, 2022). These corridors, often referred to as humanitarian corridors or safe passages, are established to ensure that aid can reach those in need and to provide a means of escape for civilians trapped in conflict zones.

Humanitarian corridors are pivotal for the delivery of food, medical supplies, and other essential resources to populations affected by war. They enable aid organizations to navigate through dangerous areas, ensuring that assistance reaches those who are most vulnerable. The establishment of these corridors requires coordination among conflicting parties, international organizations, and peacekeeping forces, highlighting the importance of diplomatic and logistical efforts in their creation and maintenance (Slim, 2015). Safe corridors also provide civilians with a means of escaping conflict zones, reducing the risk of casualties and alleviating the burden on besieged areas. The evacuation of civilians through these corridors is often a critical component of peacekeeping missions, aiming to protect non-combatants and uphold human rights. For instance, during the Syrian conflict, humanitarian corridors were established to allow civilians to flee besieged cities, which significantly reduced the number of casualties and provided much-needed relief to affected populations (UNOCHA, 2016). Moreover, corridors can facilitate negotiations and peace talks by providing neutral grounds where conflicting parties can meet. These areas could serve as zones of relative safety, encouraging dialogue and cooperation among adversaries. The presence of such neutral zones is often essential for the success of peacekeeping operations, as they help to build trust and foster communication between warring factions (Howard, 2008).

## 1.2. Ecological corridors

Similarly, ecological corridors, also known as wildlife corridors, are vital for maintaining biodiversity and facilitating the movement of wildlife between habitat patches. An ecological corridor is defined by the IUCN (Hilty et al., 2020a, 2020b) as: “A clearly defined geographical space that is governed and managed over the long term to maintain or restore effective ecological connectivity”. These corridors are often categorized into functional, structural, and regional types, each playing a crucial role in preserving the integrity of ecosystems and promoting wildlife connectivity:

### 1.2.1. Functional corridors

Functional corridors are pathways that allow species to move between habitats to fulfil their life cycle requirements. These corridors ensure genetic exchange, which is essential for maintaining genetic diversity and the long-term survival of species (Montero et al., 2019). Genetic diversity enhances the resilience of populations to environmental changes and diseases. Studies have shown that functional corridors mitigate the effects of habitat fragmentation, which can isolate populations and lead to inbreeding and local extinctions (Haddad et al., 2015). For example, the establishment of functional corridors in agricultural landscapes has proven effective in supporting the movement of pollinators such as bees and butterflies, which are crucial for crop production (Klaus et al., 2015). These corridors can include hedgerows, strips of wildflowers, and other vegetative cover that provide shelter and food resources for these species (Kremen et al., 2007).

### 1.2.2. Structural corridors

Structural corridors are physical landscape features that connect habitats. These may include riverbanks, mountain ranges, forest strips, and other natural formations that guide the movement of wildlife. Structural corridors are essential for species that rely on specific environmental conditions provided by these natural structures. They also help mitigate the impacts of climate change by allowing species to migrate to more suitable habitats as environmental conditions shift (Beier and Noss, 1998). The use of structural corridors has been observed in various wildlife species. For instance, large mammals such as elephants use riverine corridors to move between feeding and breeding grounds, ensuring their survival and reproduction. Similarly, birds often utilize mountain ridges and valleys as migratory pathways, which are critical for their seasonal movements (Hilty et al., 2020a, 2020b).

### 1.2.3. Regional corridors

Regional corridors are extensive networks that link large, geographically distinct areas. These corridors are essential for wide-ranging species and those with large home ranges, such as predators and large herbivores. Regional corridors help maintain ecosystem processes and services by supporting the movement of species across large landscapes. This connectivity is crucial for the persistence of metapopulations, which are groups of populations that interact through migration and gene flow (Bennett, 1999). An example of a regional corridor is the Yellowstone to Yukon Conservation Initiative (Y2Y), which aims to connect habitats from Yellowstone National Park in the United States to the Yukon in Canada. This initiative supports a wide array of species, including grizzly bears, wolves, and wolverines, by providing a continuous landscape that facilitates their movement and genetic exchange (Hilty et al., 2020a, 2020b).

## 2. Ecological Peace Corridors (EPCs)

Here, I propose a novel type of ecological corridor, which is an expansion of the Peace Parks idea, as a new fundamental conservation strategy to protect human and biological diversity: the Ecological Peace Corridors (EPCs). Peace Parks, also known as transboundary

conservation areas, are regions that span across national borders and are collaboratively managed to promote conservation and peace. These parks have been proposed, starting from Southern Africa, to play a crucial role in fostering biodiversity conservation while simultaneously reducing geopolitical tensions and fostering cooperation between neighbouring countries (King, 2010). Peace Parks are vital for conserving biodiversity, as they encompass large, contiguous habitats that are essential for the survival of many species. These parks often include diverse ecosystems that are less fragmented compared to isolated protected areas. This connectivity allows for greater genetic exchange and migration, which is crucial for species' adaptation to environmental changes and for maintaining healthy populations (Hilty et al., 2020a, 2020b). The Great Limpopo Transfrontier Park, which spans across Mozambique, South Africa, and Zimbabwe, is a prime example, supporting significant populations of elephants, rhinos, and large predators (Andersson et al., 2007).

Beyond ecological benefits, Peace Parks promote peace and cooperation between countries. By jointly managing natural resources, countries can reduce conflicts over resources, foster trust, and build stronger diplomatic relationships. These parks provide a neutral ground for dialogue and collaboration, which can be pivotal in conflict resolution and peacebuilding efforts (Ali, 2007). The peace process between Costa Rica and Nicaragua, facilitated by the establishment of the Corcovado and La Amistad International Parks, highlights the potential of Peace Parks to enhance regional stability (Sánchez-Azofeifa et al., 2003). Peace Parks also offer socio-economic benefits. They can boost local economies through eco-tourism, create job opportunities, and

improve the livelihoods of local communities. By involving local populations in conservation efforts, these parks ensure that conservation and development goals are mutually supportive (Wolmer, 2003). Eco-tourism driven by Peace Parks has also bolstered local economies. For example, the Kgalagadi Transfrontier Park (South Africa and Botswana) generates income for surrounding communities (Thondhlana et al., 2015). However, while Peace Parks have achieved notable successes in biodiversity conservation and fostering international collaboration, their potential is often undercut by governance issues, security challenges, and uneven economic benefits. In fact, despite efforts, poaching and security issues are still an issue and parks like the Great Limpopo Transfrontier Park struggle with illegal hunting, particularly of rhinos and elephants. Moreover, governance problems arise, such as economic gains that are not always evenly distributed, leading to local dissatisfaction in some areas where communities see limited benefits; differences in policy, funding, and enforcement between countries that have hindered effective management; and bureaucratic delays and corruption sometimes undermine initiatives (Duffy, 2001). Finally, the expansion of parks across borders often impacts local livelihoods, such as through the displacement of communities or increased wildlife threats to agriculture. Nonetheless, these transboundary conservation areas, proved to be useful in fostering ecological preservation, while allowing socio-economic development and cross-border cooperation but their effectiveness varies depending on specific regions and initiatives.

**EPCs can be strategically designed corridors that extend along national boundaries and reconnect fragmented protected areas and rewilded sites, integrating conservation efforts with the promotion**



**Fig. 1.** Ecological Peace Parks can serve as a multipurpose conservation strategy able to foster peacebuilding and peacekeeping ensuring, at the same time, protected areas' expansion and connectivity, also through rewilding, and the creation of natural buffer zones with the removal of military infrastructures.

of peace and cooperation (Fig. 1). These corridors can be essential for increasing the extent of protected and indigenous areas, enhancing connectivity between them, supporting wildlife movements, and serving as natural buffers against conflicts. Hereafter, with “conflict”, I will not only mean armed conflicts between people but also management, land-use, and human-wildlife conflicts. Additionally, EPCs can play a significant role in ensuring climatic resilience and adaptation to ecosystem shifts due to climate change.

### 2.1. EPCs to increase protected and indigenous areas

EPCs can be critical in expanding the geographical coverage of protected areas (which will also help fulfil the 30 × 30 goals). The 30 × 30 initiative, which aims to protect 30 % of the planet's land and ocean areas by 2030, is a globally ambitious conservation goal endorsed by many nations and organizations (Cazzolla Gatti et al., 2023; Robinson et al., 2024), although some critics suggest that this goal may be more difficult to achieve in some overpopulated countries, like India, without some adjustments (Sengupta et al., 2024). However, this initiative seeks to address the urgent need to halt biodiversity loss and combat climate change by significantly expanding protected areas. This expansion, coupled with strategies like ecological corridors, rewilding and land sharing, holds great promise for fostering ecological resilience and sustainability (Cazzolla Gatti, 2016).

Initiatives like the 30 × 30 and Indigenous Protected Conservation Areas (IPCAs) are rooted in the understanding that protected areas and indigenous people are essential for the conservation of biodiversity. Protected areas serve as refuges for species, allowing ecosystems to function without significant human interference. By expanding these areas to cover 30 % of the Earth's surface, the initiative aims to safeguard critical habitats, preserve genetic diversity, and support ecosystem services that are vital for human well-being (Dinerstein et al., 2019). The scientific consensus indicates that protecting large, contiguous areas is necessary to maintain ecological processes and allow species to adapt to changing environmental conditions. Moreover, this expansion can help mitigate the impacts of climate change by preserving carbon sinks, such as forests and wetlands, and by enhancing the resilience of ecosystems (Watson et al., 2016). However, without a network of interconnected protected areas that also engulf and ensure rights to part of anthropized and indigenous lands, conservation efforts can be weaker. Critics, in fact, argue that, following past “fortress conservation” approaches that have historically led to forced evictions, and restricted access to traditional lands, the expansion of protected areas can lead to the displacement of Indigenous peoples and local communities undermining indigenous rights (Survival International, 2021; Rai et al., 2021). Moreover, if they are not well integrated with local and indigenous people's rights, initiatives like the 30 × 30 could lead to land-grabbing under the guise of conservation, where corporations or governments claim lands for environmental protection without benefiting local populations (Sène, 2023).

Avoiding these troubles while setting protected areas that consider local and indigenous people's needs, rights, and contributions, EPCs can represent a win-win solution for both human beings and wildlife. By linking existing protected regions, EPCs could help to create vast, contiguous tracts of conserved land that can support larger and more stable populations of wildlife and in this way, even the areas covered by these corridors can be accounted as protected (contributing to the aimed expansion) while contributing to people and wildlife connectivity at the same time. This expansion is vital for preserving biodiversity, as it reduces the risks associated with small, isolated populations that are more vulnerable to genetic bottlenecks and local extinctions (Hilty et al., 2020a, 2020b). At the same time, buffer zones created by EPCs can alleviate conflicts with local and indigenous people by providing a gradual transition from human-dominated landscapes to natural ecosystems, reducing the severity of edge impacts and the need to set all lands aside for integral protection. Since EPCs could be, effectively,

counted as PAs (with Zone A contributing to increase strict protection towards the 10 % expansion requested by many agreements and agencies, and other zones contributing to 30 % of not-strict protection; see Zonation below), they could also help in achieving other targets (connectivity, restoration, biodiversity loss reduction, sustainable management of natural resources, rewilding, climate resilience, etc.) such as those established by the Nature Restoration Law in Europe (EC, 2024), the Kunming-Montreal Global Biodiversity Framework-CBD 2030 targets (CBD, 2024), etc.

### 2.2. EPCs to enhance protected areas connectivity and reduce edge effect

Connectivity between protected areas is crucial for maintaining ecological processes and species movement. EPCs can facilitate the movement of species between isolated habitats, allowing for genetic exchange and reducing the detrimental effects of habitat fragmentation. This connectivity also helps mitigate the edge effect, where the boundary regions of habitats are exposed to more intense environmental stressors, such as invasive species and human activities (Laurance et al., 2002). The edge effect can lead to increased predation, competition, and microclimatic changes, adversely affecting species in these border regions. For instance, increased sunlight and wind can alter the temperature and humidity, impacting species adapted to interior forest conditions (Laurance et al., 2002). Buffer zones help alleviate these conditions by providing a gradual transition from human-dominated landscapes to natural habitats, thus reducing the intensity of edge effects. By implementing buffer zones, conservation efforts can enhance habitat quality and connectivity, supporting biodiversity by ensuring that edge effects do not extend deeply into core habitats. This strategy is crucial for maintaining ecological integrity and promoting the resilience of ecosystems in fragmented areas (Ries et al., 2004).

By creating more continuous protected areas, EPCs diminish the intensity of these edge effects, promoting healthier and more resilient ecosystems.

### 2.3. EPCs to support wildlife movements and rewilding

Wildlife movements are essential for species survival, especially in the face of environmental changes and human-induced pressures. Ecological corridors play a pivotal role in maintaining ecosystem health and biodiversity. They enhance wildlife connectivity, allowing species to move freely across landscapes to access resources, find mates, and escape from predators or adverse conditions. This connectivity is crucial for the survival of many species, particularly in fragmented landscapes where human activities have disrupted natural habitats (Haddad et al., 2015). Corridors can also direct or funnel wildlife movements thereby helping to prevent human-wildlife conflicts and negative human-wildlife encounters (Hilty et al., 2020a, 2020b). Moreover, corridors contribute to ecosystem functioning that benefits human populations. For instance, by supporting pollinators and other beneficial species, they enhance agricultural productivity and food security. Corridors also play a role in climate regulation, water purification, and soil conservation, which are essential for human well-being (Kremen et al., 2007). The preservation and creation of ecological corridors require collaborative efforts involving conservationists, landowners, policymakers, and the public. Effective corridor design considers the ecological needs of the target species, the landscape context, and the potential barriers to connectivity. Monitoring and adaptive management are also essential to ensure that corridors continue to function effectively over time (Beier and Noss, 1998). Connecting protected areas through ecological corridors, ecosystem restorations, and rewilding projects is essential for maintaining biodiversity, enhancing ecosystem resilience, and promoting long-term conservation success. These strategies collectively mitigate habitat fragmentation, which is a leading cause of biodiversity loss (Hilty et al., 2020a, 2020b). Ecological corridors serve as vital links between isolated protected areas, allowing species to move freely across

landscapes. This movement is crucial for gene flow, which helps maintain genetic diversity and population health. Corridors also enable species to migrate in response to environmental changes, such as climate shifts, ensuring their survival in the face of global change (Haddad et al., 2015). For example, the European Green Belt connects fragmented habitats across multiple countries, promoting wildlife movement and conservation across political boundaries (Terry et al., 2006).

Ecosystem restoration involves rehabilitating degraded habitats to their natural conditions. This process not only restores the ecological functions of an area but also enhances habitat connectivity. Restoration efforts can include reforestation, wetland rehabilitation, and grassland management, all of which contribute to creating contiguous habitats that support diverse species (Benayas et al., 2009). Restored ecosystems act as stepping stones that facilitate the movement of species between protected areas, bolstering overall landscape connectivity.

Rewilding aims to restore ecosystems by reintroducing native species and allowing natural processes to resume. This approach can create dynamic environments where keystone species, such as large predators, help regulate ecosystems, leading to increased biodiversity and resilience (Perino et al., 2019). Rewilding projects, like the restoration of the Scottish Highlands with native species such as lynx and wild boar, demonstrate how rewilding can reconnect fragmented habitats and enhance ecological networks (Monbiot, 2013).

EPCs can provide safe passages for migratory species and support the natural movement patterns of wildlife. This is particularly important for large mammals and apex predators, which require extensive ranges to find food, mates, and suitable habitats. Additionally, EPCs can facilitate rewilding projects, where native species are reintroduced to restore ecological balance and biodiversity. The Yellowstone to Yukon (Y2Y) corridor in North America exemplifies how EPCs can support both wildlife movements and rewilding efforts, ensuring ecological integrity across vast landscapes (Hilty et al., 2020a, 2020b).

EPCs could also contribute to achieving the goals of international agreements and goals such as the Convention on Migratory Species (CMS), the Aichi Biodiversity Targets, and the Sustainable Development Goals (SDGs) by supporting biodiversity and ecosystem health. By enabling migratory species to move safely, reducing habitat fragmentation and helping them shift their ranges to more suitable areas, ensuring long-term survival during climate change, EPCs can be a relevant tool for the CMS. Moreover, most of the Aichi Biodiversity Targets (particularly targets 5, 11, 12 and 15 related to habitat fragmentation, protected areas integration, prevent extinctions, and climate resilience) could benefit from the implementation of EPCs. Finally, EPCs could support important steps towards SDGs, particularly those related to Peace (Goal 16), Life on Land (Goal 15), Climate Action (Goal 13), etc.

EPCs implementation could also align with existing platforms such as the Environmental Peacebuilding Knowledge Platform (<https://www.environmentalpeacebuilding.org/>), which aims to find solutions that integrate natural resource management in conflict prevention, mitigation, resolution, and recovery to build resilience in communities affected by conflict.

#### 2.4. EPCs to provide natural buffer zones during conflicts and war

Buffer zones can play a critical role in mitigating conflicts, whether between human communities during wars or between humans and wildlife. In the context of wars and human conflicts, buffer zones act as neutral territories that reduce direct encounters between opposing forces. These areas help to de-escalate tensions and prevent accidental or intentional incursions that could reignite hostilities. For example, the demilitarized zone (DMZ) between North and South Korea has been a critical buffer since the Korean War armistice in 1953, preventing direct military engagement and providing a space for potential diplomatic engagements (Chun et al., 2009). Buffer zones can also facilitate humanitarian efforts by providing safe passage for aid deliveries and civilian evacuations. These zones are often monitored by peacekeeping

forces, ensuring compliance with ceasefires and contributing to stability in conflict regions (Diehl, 1994).

In environmental contexts, buffer zones are vital for reducing human-wildlife conflicts. These zones create transitional areas between human settlements and wildlife habitats, minimizing encounters that could lead to crop damage, livestock predation, and human injuries or fatalities. For example, buffer zones around protected areas in India have been instrumental in reducing conflicts with tigers and elephants by providing alternative habitats and resources for wildlife (Ghosh-Harihar et al., 2019). Moreover, buffer zones enhance conservation efforts by maintaining habitat connectivity and allowing wildlife to move safely between protected areas. They can include measures like fencing, land use regulations, and community-based conservation programs that involve local populations in managing and benefiting from wildlife conservation (Woodroffe and Thirgood, 2005). Moreover, buffer zones that surround protected areas are important in minimizing the edge effect and serve to mitigate adverse effects from adjacent land uses and act as transitional regions, reducing the impact of human activities on core conservation areas (Murcia, 1995).

EPCs can serve as natural buffer zones that can reduce the likelihood of conflicts and wars. By establishing these corridors, neighbouring countries can work together on conservation initiatives, fostering cooperation and peace. These buffer zones help mitigate tensions by providing neutral areas that both countries benefit from, thereby reducing the chances of territorial disputes and resource conflicts. The demilitarized zone (DMZ) between North and South Korea, which has inadvertently become a haven for biodiversity, demonstrates the potential for such corridors to serve dual purposes of conservation and peacebuilding (Ali, 2007). Clearly, during an active conflict, it could be very difficult to set new EPCs because of practical issues (security, diplomacy, etc.). Instead, EPCs could be considered instrumental for peacebuilding (before the start of a conflict) or peacekeeping (after a conflict ends), rather than as a ceasefire tool (able to stop a conflict). However, since we already know hotspots of potential conflicts in the world and areas that are living in a “temporary calm” after a recent conflict, dedicated taskforces, which could be made by a combination of scientists, NGOs, policymakers, and diplomats from neighbouring countries and international bodies (e.g. UNEP, UNHCR, etc.) may organize stakeholder roundtables to develop a strategy to build EPCs as a parallel cooperation strategy before any armed conflict will potentially restart.

A further positive aspect of EPCs could be that they can be used where management approaches differ across neighbouring countries and thereby help resolve conflicts that emerge from these differences. For instance, the cross-border bull elephants moving between Kenya and Tanzania raised controversy over trophy-hunting on the Tanzania side (Poole et al., 2024). Such a situation and conflict could be reconciled by the creation of strategically placed EPCs helping to reconnect transboundary movement corridors and delineating where elephants are safe from hunting. This could be further extended to secure the movements of cross-boundary Peoples (in the Kenya-Tanzania example, of Maasai and their herds). Overall, transboundary governance could be improved through EPCs if both wildlife and people benefit.

#### 2.5. EPCs to ensure climatic resilience and adaptation

The northward and upward movements of species distribution are significant ecological responses driven by climate change. Many species are shifting their ranges towards higher latitudes (northward) or altitudes (upward) in search of suitable climatic conditions. This phenomenon has been documented across various taxa, including plants, animals, and marine organisms.

One of the primary drivers of these shifts is the need for species to maintain their thermal niches. For example, Parmesan and Yohe (2003) demonstrated that over 1700 species exhibited significant poleward or upward shifts, consistent with warming trends observed over the past

century. This has been particularly evident in mountainous regions, where species migrate to higher elevations as lower elevations become too warm, leading to changes in community composition and local biodiversity. The upward movement, however, is constrained by the availability of suitable habitats, potentially leading to range contractions and even local extinctions (Colwell et al., 2008). These movements can disrupt existing ecological balances, leading to altered predator-prey relationships and competition dynamics.

The northward and upward shifts also have implications for conservation strategies. Traditional protected areas may no longer encompass the necessary habitats for species whose ranges are shifting, necessitating dynamic conservation approaches (Titley et al., 2021). Moreover, species that cannot move fast enough or are limited by geographic barriers face an increased risk of extinction. These shifts in species distributions due to climate change are reshaping ecosystems and challenging conservation efforts, highlighting the need for proactive and flexible management strategies (Pecl et al., 2017).

EPCs can be crucial in facilitating these northward and upward movements, providing pathways for species to migrate in response to changing environmental conditions. By connecting habitats across different elevations and latitudes, EPCs can enhance the resilience of ecosystems to climate change, ensuring that species can adapt and survive (Heller and Zavaleta, 2009). These corridors also help maintain the integrity of ecosystem functioning, such as water regulation, carbon sequestration, and soil fertility, which are vital for both biodiversity and human communities.

### 3. A proposed methodology to identify priority EPCs on Earth

In a world in constant, intra and inter-specific human conflicts, to speed up the definition of essential EPCs there is the need to support human intelligence with artificial intelligence. A first proposal, already tested in selected study sites, is suggested as follows:

#### 3.1. Gap analysis to identify priority areas

Gap analysis in conservation planning plays a crucial role in identifying priority areas for connectivity and ensuring effective management of biodiversity. This approach systematically assesses the representation of different habitats and species within protected areas and identifies gaps where additional conservation efforts are needed (Fig. 2).

Gap analysis helps conservationists prioritize areas for habitat restoration, establishment of new protected areas, or creation of ecological corridors. By identifying gaps in the conservation network, planners can focus resources on connecting fragmented habitats,

thereby promoting species movement, gene flow, and resilience to environmental changes (Margules and Pressey, 2000).

The process typically involves integrating spatial data on land cover, species distributions, and ecological processes with conservation goals and, in the case of EPCs, also of risky and conflict border zones (An et al., 2023). Geographic Information Systems (GIS) and remote sensing technologies play crucial roles in spatially analyzing data and visualizing gaps in habitat connectivity (Scott et al., 2001). Conservation planners use various metrics, such as habitat quality, proximity to existing protected areas, and landscape connectivity, to prioritize areas for conservation actions (Carwardine et al., 2008).

Gap analysis has been applied globally to guide conservation efforts across different scales, from local to regional and international levels. For example, the identification of key biodiversity areas (KBAs) and Important Bird and Biodiversity Areas (IBAs) through gap analysis has influenced policy and conservation strategies worldwide (Langhammer et al., 2007).

#### 3.2. Land cover classification with Artificial Intelligence to select relevant areas

Land cover classification using artificial intelligence, particularly machine learning algorithms like Random Forest, has revolutionized the field of remote sensing. This approach leverages the power of statistical learning to analyze satellite imagery and categorize land cover types accurately and efficiently. Machine learning (ML) algorithms, such as decision trees, support vector machines (SVMs), and neural networks, are increasingly utilized for land cover classification. These algorithms learn from labelled training data to identify patterns and make predictions on new, unseen data. For instance, Random Forest, an ensemble learning method, has proven effective in handling high-dimensional remote sensing data, offering robustness and high classification accuracy (Belgiu and Drăguț, 2016).

In remote sensing applications, Random Forest has been widely employed for land cover mapping and change detection. It excels in distinguishing between different land cover classes such as forests, urban areas, water bodies, and agricultural land based on spectral signatures and spatial patterns captured by satellite sensors (Foody, 2002). Studies have demonstrated the effectiveness of Random Forest in achieving high classification accuracies comparable to or even exceeding those of traditional methods (Cutler et al., 2007).

One of the key advantages of Random Forest is its ability to handle noisy and incomplete data while providing measures of feature importance, which helps in understanding the contributions of different spectral bands or features to the classification results (Breiman, 2001).

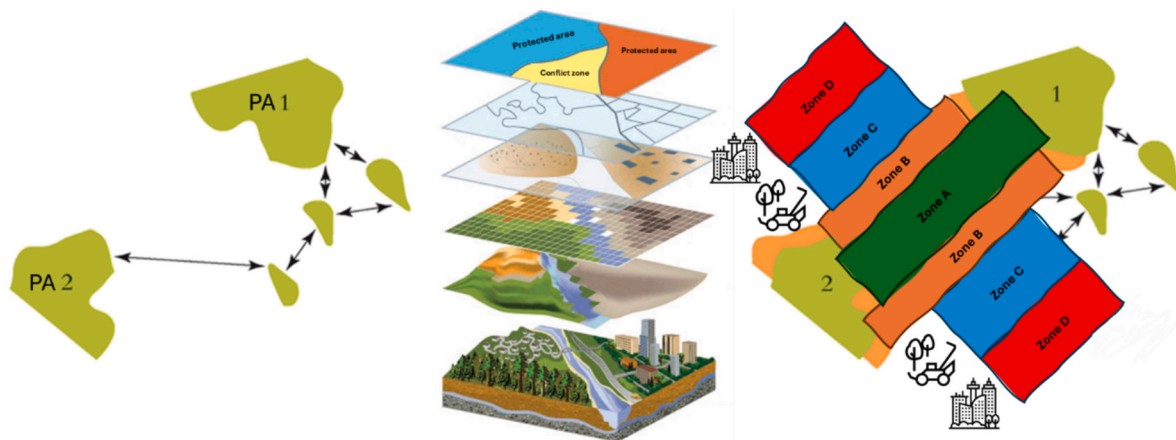


Fig. 2. – Gap analysis is fundamental in the process of identification of EPCs because it allows to envision the best pathways for connectivity (left figure) by overlapping (centre figure) different layers of relevant features (protected areas, conflict zones, forest cover, wildlife habitats, etc.) and to identify the zones (right figure) that could contribute to increasing the connectivity between PAs and, at the same time, reduce the human-human and human-wildlife conflicts.

Moreover, its scalability allows for processing large-scale datasets efficiently, facilitating timely updates and monitoring of land cover changes over time (Fig. 3).

### 3.3. Least Coast Path (LCP) to identify the optimal corridors and reduce social impacts

The Least Cost Path (LCP) analysis is a powerful spatial modeling technique used in landscape ecology and conservation planning to identify optimal ecological corridors while minimizing social impacts such as land grabbing (Fig. 2). This approach calculates the path of least resistance or cost between two points, often considering factors like land cover, topography, and human infrastructure. In the context of ecological peace corridors (EPCs), LCP analysis helps identify routes that facilitate wildlife movement and ecosystem connectivity with minimal disruption to human activities and communities and would be informative to apply in areas where wildlife and farmers share space, for example at the Kenya-Tanzania border. By modeling least-cost paths, planners can pinpoint corridors that traverse through suitable habitats while avoiding densely populated areas and including areas prone to conflicts (Adriaensen et al., 2003).

One of the key advantages of LCP analysis is its ability to integrate social and ecological considerations into corridor planning. By incorporating socioeconomic data and stakeholder input, planners can prioritize corridors that minimize social impacts such as displacement of communities or conflicts over land tenure (Bennett and Mulongoy, 2006).

Scientific studies have demonstrated the efficacy of LCP analysis in various conservation contexts, including the establishment of wildlife corridors and connectivity networks. For example, research in conservation genetics has used LCP to predict gene flow and species movement patterns across fragmented areas, contributing to effective biodiversity conservation strategies (Spear et al., 2010).

### 3.4. Zonation to allow wilderness reconnection and traditional sustainable activities

To be able to increase biological conservation, reconnect protected areas and still allow the existence of traditional sustainable human activities, here I propose that EPCs should follow the Italian system of

National Park zonation, structured into Zones A, B, C, and D, which serves as a framework for managing and conserving biodiversity while accommodating various human activities within protected areas (Speranza et al., 2012; Nardi et al., 2014; Baldaccini and Speranza, 2017; Ciolli and Santolini, 2019). The zonation system in Italian National Parks reflects an integrated approach to conservation, integrating ecological, social, and economic objectives. It aims to maintain biodiversity, protect ecosystem functioning, support sustainable development, and foster community involvement in conservation efforts, which can be easily translated into the EPCs. This zonation includes participatory mapping with local communities and stakeholders, aligning with country-specific designation of lands, buffer zones, and protected areas.

Therefore, EPCs could be planned in the following way (Fig. 1):

- **Zone A (Strict corridor):** This zone represents the core area of the EPC where human activities are strictly limited or prohibited (except for special cases such as indigenous people's rights), and wildlife is strictly protected (which would contribute to the 10 % of strict protection requested by many environmental agreements and agencies). It serves as a sanctuary for wildlife and habitats, allowing natural processes to occur without human interference. Zone A - which can extend from a few hundred meters to some kilometres, depending on the local conditions and is mainly composed of natural extant or restored vegetation - is crucial for preserving biodiversity in sensitive conflict zones.
- **Zone B (General corridor):** In this zone, sustainable recreational activities and low-impact tourism are typically permitted under regulated conditions. This zone aims to strike a balance between conservation goals and human use, providing opportunities for visitors to experience and appreciate nature while minimizing disturbances to wildlife. These strips of land - which can also extend from a few hundred meters to some kilometres, depending on the local conditions - are placed on the two sides of Zone A and are still made of natural extant or restored endemic vegetation.
- **Zone C (Partial corridor):** this zone allows for controlled activities such as traditional agriculture, forestry, and sustainable land use practices. It supports local communities by maintaining cultural landscapes and traditional livelihoods while ensuring that these activities do not compromise the ecological integrity of the corridor. This area, at both sides of Zone B - which can also extend from a few

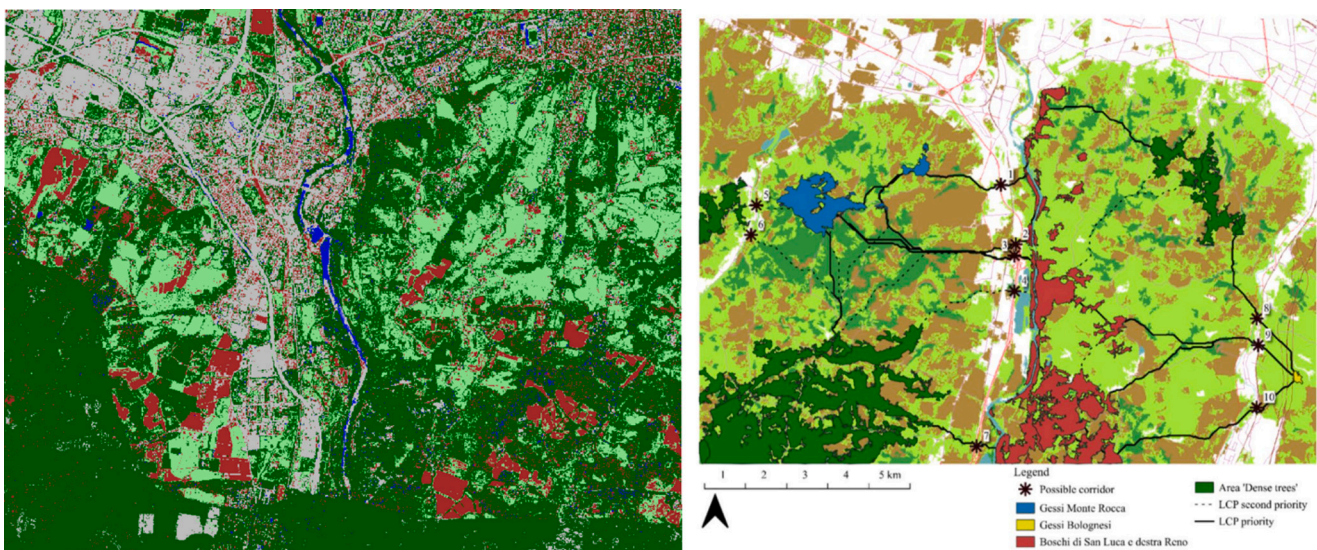


Fig. 3. – Random Forest (RF) was used to classify a complex mosaic landscape (the Apennine region in the south of Bologna Municipality, Italy) and differentiate between forested, agricultural, urban, and water areas (left figure). Then, based on this classification, Least Coast Path (LCP) was used, in combination with a resistance matrix with higher costs assigned to anthropized areas, to identify the best corridors (lines) and the barriers to by-pass (stars) to reconnect extant protected areas (right figure from a study commissioned by the Municipality of Bologna, Italy, on the Reno river to the author's research team; Vandelli et al., 2025).

hundred meters to some kilometres, depending on the local conditions – is made by a mix of natural vegetation and plantations that still provide important corridors for species and, at the same time, ecological processes and natural resources for local populations.

- **Zone D (Transition or Buffer corridor):** this zone acts as a buffer between the protected core areas and surrounding human-dominated landscapes. It permits more intensive human activities, including infrastructure development and certain types of agriculture, under strict regulations aimed at minimizing impacts on adjacent ecosystems. This area, at both sides of Zone C - which extends towards the more urbanized or populated areas – is made by a mix of touristic facilities and infrastructures, plantations, and agricultural areas. Moreover, in this zone - mainly falling within conflict areas – military activities (surveillance, vehicle traffic, border infrastructure, outposts, etc.) can be located and serve for both peacekeeping and ecological/wildlife patrolling.

#### 4. Examples of urgent ECPs in conflict zones

Military infrastructures such as walls, barriers, and bases can have significant negative impacts on wildlife and ecosystems in conflict zones (Vidal et al., 2013; Nowak et al., 2024). These structures often fragment areas, disrupt wildlife movement, and lead to biodiversity loss and degradation. For example, border walls along the US-Mexico border have been shown to impede the movement of species such as jaguars and ocelots, reducing genetic diversity and hindering population viability (Ruiz-Mallén et al., 2020).

The establishment of Ecological Peace Corridors (EPCs) offers a promising solution by removing these barriers and restoring natural vegetation. EPCs reconnect fragmented habitats, facilitate wildlife migration, and promote species resilience to environmental changes. By creating patrolled ecological areas, where conservation efforts are coordinated and enforced, EPCs can mitigate human-wildlife conflicts and provide shared spaces for cross-border cooperation on environmental stewardship.

Scientific evidence supports the effectiveness of such approaches in promoting biodiversity conservation and peacebuilding. For instance, initiatives like the Transboundary Peace Parks in southern Africa have demonstrated that joint conservation efforts across international borders can foster cooperation and reduce tensions among neighbouring countries (Jones, 2009; Mackelworth, 2012; Macaspac and Moore, 2024).

Ecological Peace Corridors (EPCs) offer a dual opportunity to promote both peacebuilding efforts and biodiversity conservation in conflict zones across various borders, including for example Rwanda-Tanzania-Uganda-DRC, Russia-Ukraine-Belarus-Poland, Palestine-Israel, US-Mexico, and China-India-Pakistan. These corridors can play a crucial role in mitigating conflict and enhancing environmental sustainability by removing military infrastructures, restoring natural vegetation, and establishing patrolled ecological corridors.

##### 4.1. Rwanda, Tanzania, Uganda, and DRC Border

The Great Lakes region, including parts of Rwanda, Tanzania, Uganda, and the Democratic Republic of Congo (DRC), has been marred by conflicts over resources and political instability. EPCs in this area could connect fragmented habitats, support migratory routes for wildlife, and provide opportunities for joint conservation efforts. By removing military infrastructures, such as checkpoints and military bases, and establishing patrolled ecological corridors, these regions can foster trust among neighbouring countries and promote cooperation through shared environmental stewardship based on legal or diplomatic mechanisms that are based on natural resources conflict management strategies.

##### 4.2. Russia, Ukraine, Poland, and Belarus Border

The Russia-Ukraine-Poland-Bielorussia border has been a focal point of geopolitical tensions, but it also harbours diverse ecosystems, protected areas, and wildlife habitats (including one of the largest and last old-growth forests of Europe, the Białowieża Forest). EPCs here could facilitate biodiversity conservation by reconnecting fragmented areas created by human activities and military presence (Błaszczuk et al., 2024). Restoring natural vegetation and implementing patrolled corridors could provide safe passage for species and promote cross-border dialogue on environmental issues, potentially easing political tensions.

##### 4.3. Palestine and Israel Border

The border between Palestine and Israel is marked by conflict and division, but it also traverses ecologically rich landscapes. EPCs along this border could integrate conflict zones and mitigate environmental degradation exacerbated by political conflict. Also, in this case, the removal of military infrastructures and the establishment of patrolled ecological corridors could enhance biodiversity conservation while providing shared spaces for environmental cooperation and dialogue.

##### 4.4. US and Mexico Border

The US-Mexico border, characterized by border walls and security infrastructure, disrupts wildlife movements and threatens biodiversity. EPCs in this region could restore natural habitats, facilitate wildlife corridors, and promote sustainable land management practices. By removing barriers and establishing patrolled ecological corridors, both countries can favour biodiversity conservation, mitigate ecological fragmentation, and foster cross-border cooperation on environmental issues. Moreover, EPCs would contribute to existing efforts in the region (Arizona Capitol Times, 2023) for example in the creation of wildlife openings and cross-border corridors that should be designed for maximum wildlife permeability (Peters et al., 2018).

##### 4.5. India, Pakistan, and China Border

The border between India, Pakistan, and China particularly in regions like the Pamir Plateau, where transboundary migration of Marco Polo Sheep is threatened (Schaller and Kang, 2008) and Kashmir, which is heavily militarized, posing challenges to both peace and biodiversity conservation. EPCs in this area could connect fragmented habitats, support wildlife migration routes, and mitigate human-wildlife conflicts. Here too, removing military infrastructures, restoring natural vegetation, and establishing patrolled corridors could create shared spaces for environmental stewardship, promoting peacebuilding efforts through collaborative conservation initiatives.

#### 5. Monitoring the effectiveness of EPCs for biodiversity and peacekeeping

Monitoring the effectiveness of Ecological Peace Corridors (EPCs) over time is crucial for assessing biodiversity conservation outcomes and ensuring the success of these conservation initiatives. Various monitoring approaches can be employed to evaluate different aspects of EPCs, such as:

1. **Camera Traps:** Deployed strategically along EPCs, camera traps to capture images and videos of wildlife movements. They provide valuable data on species presence, behaviour, and population dynamics, helping assess the effectiveness of corridors in facilitating wildlife movement and connectivity. Moreover, camera traps can help surveillance for peacekeeping limiting the violation of no-conflict zones and the unauthorized movement of people.

2. **Soundscape:** Acoustic monitoring records natural sounds and vocalizations of species within EPCs. Analyzing the soundscape helps monitor changes in biodiversity and ecosystem health, providing insights into species diversity and habitat use (as well as recording sounds from weapons in the surrounding areas).
3. **Environmental DNA (eDNA):** This approach involves collecting and analyzing DNA fragments from soil, water, or air samples to detect the presence of species, especially rare or elusive ones. eDNA can identify species (and even human presence) using traces left in the environment without direct sightings.
4. **Drones:** Where permitted or with special authorizations in military zones, unmanned aerial vehicles (drones) equipped with sensors and cameras can monitor land changes, habitat fragmentation, and vegetation dynamics within EPCs. They provide high-resolution imagery for assessing habitat quality and identifying potential threats (including movements of people within the corridor).
5. **Canopy Surveys:** These surveys involve climbing or using elevated platforms to study species that inhabit tree canopies within EPCs. Monitoring canopy species helps evaluate recolonization efforts and assess habitat suitability over time. Additionally, they can represent privileged observation points to patrol human activities within the corridor and at its borders.
6. **Satellite Remote Sensing:** Remote sensing technologies from satellites provide comprehensive data on land cover changes, habitat fragmentation, and ecosystem dynamics at larger spatial scales. This information aids in monitoring landscape-level impacts on EPCs and potential unauthorized land cover changes and illegal expansion of settlements.

By integrating these monitoring approaches, conservationists can gather comprehensive data on biodiversity trends, habitat connectivity, and ecosystem resilience within Ecological Peace Corridors and policymakers can ensure long-term peacekeeping. Continuous monitoring allows for adaptive management strategies, ensuring that EPCs effectively support wildlife conservation and contribute to peacebuilding efforts across conflict zones.

## 6. Conclusion

Ecological corridors are indispensable for preserving biodiversity and ensuring the resilience of ecosystems. Functional, structural, and regional corridors each play unique roles in facilitating wildlife movement and genetic exchange, thereby supporting healthy populations and ecosystems. As human activities continue to fragment natural habitats, the importance of these corridors will only grow, underscoring the need for proactive conservation strategies and sustainable land-use planning.

The 30 × 30 protected areas expansion is a critical step towards conserving global biodiversity and addressing climate change. However, to achieve its full potential, it must be complemented by land sparing through rewilding projects and land sharing in anthropized areas with special attention to local and indigenous people's rights. Rewilding restores ecosystems to natural states, enhancing ecological processes and resilience. Land sharing integrates conservation into human-dominated landscapes, promoting coexistence and connectivity. Together, these strategies can create a more sustainable and resilient planet, ensuring the well-being of both nature and humanity. At the same time, buffer zones are essential tools for conflict mitigation, offering neutral spaces that reduce direct confrontations and enhance safety for both humans and wildlife. By promoting coexistence and stability, these zones play a key role in conflict resolution and conservation strategies.

Integrating ecological corridors, ecosystem restorations, and rewilding projects is paramount for connecting protected areas and ensuring the long-term viability of wildlife populations. These strategies enhance habitat connectivity, promote genetic diversity, and increase ecosystem resilience, ultimately contributing to global conservation goals.

Ecological Peace Parks could be a new powerful tool for biodiversity conservation and international peacekeeping. They highlight the interconnectedness of environmental health and human diplomacy, showcasing how collaborative management of natural resources can lead to sustainable and peaceful coexistence.

Ecological Peace Corridors can become indispensable for modern conservation strategies, offering a win-win approach that integrates biodiversity preservation with geopolitical stability. By increasing protected area network integrity and extension, enhancing connectivity, supporting wildlife movements and rewilding, acting as buffer zones against conflicts, and ensuring climatic resilience, EPCs provide a multifaceted solution to the intertwined challenges of biodiversity loss, climate change, and human conflict. Their implementation requires international cooperation, long-term planning, and a commitment to both ecological and human well-being.

A first methodology was proposed, which involves: 1) AI-ML (such as Random Forest algorithm) to advance land cover classification in remote sensing, offering robustness, accuracy, and scalability for analyzing satellite imagery; 2) Gap analysis to enable the systematic identification of priority areas for connectivity and peacekeeping; 3) Least Cost Path analysis to optimize ecological peace corridors by balancing ecological needs with social considerations.

By identifying routes that offer the least resistance to wildlife movement while respecting human land use patterns and rights, LCP contributes to sustainable development and conflict mitigation efforts. Then, the Italian zonation system of National Parks, which provides a flexible and adaptive framework for the planning of EPCs, was suggested to balance conservation imperatives with human needs.

Ecological Peace Corridors can offer a systemic approach to addressing both environmental and geopolitical challenges in conflict zones. By removing military infrastructures (such as in the case of the Slovenia-Croatia border, where this process is happening mainly for political reasons but could benefit nature connectivity and wildlife movements; AP, 2022), restoring natural vegetation, and establishing patrolled ecological corridors, these regions can enhance biodiversity conservation, mitigate ecological fragmentation, and promote peacebuilding through shared environmental stewardship. These efforts not only benefit wildlife and ecosystems but also foster cooperation and trust among neighbouring countries, laying the foundation for sustainable development and peace in conflict-affected areas.

## CRediT authorship contribution statement

**Roberto Cazzolla Gatti:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization.

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No data was used for the research described in the article.

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