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CPEC AND ENVIRONMENTAL CHANGE IN PAKISTAN: ASSESSING IMPACTS ON ECO-SYSTEMS, WATER RESOURCES, AND BIODIVERSITY

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Abstract
The China–Pakistan Economic Corridor (CPEC), a flagship initiative of China's Belt and Road Initiative, plays a significant role in Pakistan's economic development and regional connectivity. However, its infrastructure, energy, and industrial projects raise environmental concerns regarding ecosystem degradation, water-resource management, and biodiversity conservation. This study examines the environmental implications of CPEC in Pakistan, focusing on habitat fragmentation, water pollution, resource depletion, and threats to wildlife. It adopts a qualitative research methodology based on secondary data collected from academic publications, government reports, environmental assessments, and international organizations. The study employs sustainable development theory and environmental governance perspectives to analyze the relationship between infrastructure expansion and ecological sustainability. The analysis highlights the importance of effective environmental impact assessments, institutional coordination, climate-resilient infrastructure, and community participation. It recommends integrated water management, biodiversity protection, transparent monitoring, and stronger environmental regulations to ensure that CPEC promotes sustainable economic growth while safeguarding Pakistan's natural resources for future generations.

INTRODUCTION
The China–Pakistan Economic Corridor (CPEC) is a major economic and infrastructure development initiative connecting China's Xinjiang region with Pakistan's Arabian Sea coast. As a flagship component of China's Belt and Road Initiative (BRI), CPEC aims to improve regional connectivity, expand energy production, promote industrial development, and facilitate trade and investment between Pakistan and China. Its projects include transportation networks, energy facilities, industrial zones, and port-related infrastructure. Although these initiatives offer opportunities for economic growth and regional

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integration, they also raise important questions concerning environmental sustainability, natural-resource management, and ecological conservation (Ali & Askari, 2023).

Environmental sustainability has become an important dimension of contemporary development studies because economic progress can generate significant ecological costs when natural resources are used without adequate safeguards. The World Commission on Environment and Development (1987) emphasized the need to balance present development requirements with the environmental needs of future generations. In the context of CPEC, this principle requires infrastructure development to be assessed not only in terms of economic benefits but also in relation to its potential effects on ecosystems, freshwater supplies, wildlife habitats, and the long-term environmental well-being of local communities. Pakistan possesses diverse ecological landscapes, including the mountainous regions of Gilgit-Baltistan, the forests and river systems of Khyber Pakhtunkhwa, the agricultural plains of Punjab and Sindh, the arid environments of Balochistan, and the coastal ecosystems along the Arabian Sea. These environments support agriculture, tourism, fisheries, livestock production, and local livelihoods. However, infrastructure expansion, industrialization, urbanization, and increasing demand for natural resources may intensify existing environmental pressures. Consequently, CPEC's environmental implications need to be examined within Pakistan's wider ecological and socioeconomic context rather than being treated exclusively as a matter of engineering or economic planning.

Infrastructure development can affect ecosystems through land conversion, vegetation clearance, soil disturbance, habitat fragmentation, and changes in natural drainage systems. Road construction in mountainous areas, for example, may require excavation and slope cutting, potentially increasing erosion and landslide risks where environmental safeguards are inadequate. Industrial facilities and expanding settlements may also contribute to pollution and changes in land use. Research examining the relationship between CPEC and Pakistan's natural environment has identified environmental sustainability as an important concern alongside the corridor's development opportunities (Ali & Askari, 2023). Nevertheless, the scale and severity of individual impacts must be established through project-specific evidence rather than assuming that all CPEC projects produce identical environmental consequences. Water resources represent another essential dimension of the relationship between CPEC and environmental change. Pakistan relies heavily on the Indus River system for irrigation, electricity generation, drinking water, and other economic activities. Infrastructure construction may affect water quality through sediment runoff, construction waste, and the inadequate management of wastewater. Depending on their design and location, energy and industrial projects may also increase freshwater demand or alter riverine environments. Research on surface water and terrestrial water storage in the CPEC region highlights the importance of understanding the combined influences of human activities and climate change on regional water systems (see Changes in Surface and Terrestrial Waters in the China–Pakistan Economic Corridor Due to Climate Change and Human Activities, 2024). Effective water management is therefore essential to protect both human needs and aquatic ecosystems (Ismail, et,al, 2025).

Biodiversity conservation is closely connected to the environmental sustainability of CPEC. Pakistan's ecosystems provide habitats for wildlife, native vegetation, and numerous species that contribute to ecological balance and human livelihoods. Transportation corridors may fragment habitats, interrupt wildlife movement, and increase disturbance in environmentally sensitive areas. Similarly, port development and industrial expansion can place pressure on coastal habitats if dredging, waste disposal, and pollution are inadequately managed. The Convention on

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Volume 4 • Issue 6 • October 2026

Biological Diversity (1992) provides an international framework for conserving biodiversity and promoting the sustainable use of biological resources. Applying these principles to CPEC requires ecological surveys, habitat protection, responsible land-use planning, and effective monitoring of environmental impacts. Climate change further complicates the environmental challenges associated with infrastructure development in Pakistan. The country is exposed to floods, heatwaves, droughts, changing precipitation patterns, and climate-related risks affecting mountain and river systems. These challenges are particularly relevant to infrastructure located in mountainous regions, where instability, heavy rainfall, and glacial hazards slope can threaten roads, bridges, settlements, and surrounding ecosystems. The Government of Pakistan's National Climate Change Policy 2021 emphasizes climate-resilient and low-carbon development as important national priorities (Government of Pakistan, 2021). Consequently, CPEC planning should incorporate climate-risk assessments, disaster preparedness, sustainable energy choices, and measures to protect vulnerable ecosystems from additional environmental pressure. Environmental governance is essential for ensuring that CPEC's economic benefits do not come at the expense of ecological sustainability. Environmental impact assessments, pollution-control standards, institutional coordination, and public participation are important mechanisms for identifying and managing the risks associated with development projects. Pakistan's environmental regulatory framework, including the Pakistan Environmental Protection Act, 1997, provides a legal basis for environmental protection and pollution control. However, the effectiveness of these mechanisms depends on implementation, monitoring capacity, transparency, and enforcement. Environmental assessments should examine not only the immediate effects of individual projects but also their cumulative consequences for watersheds, habitats, and local communities. Stronger coordination among federal and provincial institutions can help integrate environmental considerations into CPEC planning and implementation.

Although existing research has examined the relationship between CPEC and environmental sustainability, further integrated analysis is needed to understand the connections among ecosystem change, water resources, biodiversity, and environmental governance. Ali and Askari (2023), for example, investigated environmental risks associated with CPEC development projects and highlighted concerns related to Pakistan's natural environment. Other research has examined changing water availability and ecological conditions across the CPEC region. Nevertheless, environmental impacts vary across geographical locations and project types, making it necessary to distinguish documented changes from potential risks. A comprehensive approach should therefore combine academic literature, government policies, environmental assessments, and reports from relevant international organizations to develop a clearer understanding of the relationship between infrastructure development and ecological protection.

The CPEC and environmental change in Pakistan, focusing on ecosystems, water resources, and biodiversity. Its principal objective is to evaluate the environmental risks associated with infrastructure, energy, and industrial development while considering the role of environmental governance in reducing these risks. Using a qualitative methodology based on secondary sources, the study analyzes relevant academic publications, government documents, environmental policies, and institutional reports. Sustainable development theory and environmental governance provide the analytical foundation for understanding how economic growth can be reconciled with ecological protection. The study argues that CPEC's long-term contribution to Pakistan's development depends not only on investment and connectivity but also on effective environmental regulation,

JOURNAL FOR SOCIAL SCIENCE STUDIES
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Volume 4 • Issue 6 • October 2026

climate-resilient planning, biodiversity conservation, and the sustainable management of natural resources.

Research Methodology

This study adopts a qualitative research methodology to examine the environmental implications of the China–Pakistan Economic Corridor (CPEC) in Pakistan, focusing on ecosystems, water resources, and biodiversity. The research is based on secondary data collected from peer-reviewed journal articles, academic books, government reports, environmental impact assessments, policy documents, and publications by international organizations, including the World Bank and the Intergovernmental Panel on Climate Change (IPCC). These sources provide relevant information about infrastructure development, environmental change, natural-resource management, and biodiversity conservation in Pakistan (Sumra, 2025).

The collected data are analyzed through qualitative thematic analysis, focusing on three major themes: ecosystem degradation, water-resource management, and biodiversity conservation. Sustainable Development Theory and environmental governance perspectives guide the analysis by examining how infrastructure development can be balanced with ecological protection and institutional accountability (World Commission on Environment and Development, 1987). The study identifies major environmental concerns, evaluates policy and governance challenges, and proposes recommendations for sustainable CPEC development. However, because the research relies on secondary sources, project-specific environmental impacts require further verification through field studies and environmental monitoring.

Theoretical Framework

Sustainable Development Theory

Sustainable development provides the principal theoretical perspective for this study. The concept, prominently articulated in the 1987 report of the World Commission on Environment and Development, *Our Common Future*, defines sustainable development in terms of meeting present needs without compromising the ability of future generations to meet their own needs. This perspective challenges the assumption that economic growth should be evaluated only through investment, infrastructure, employment, or gross domestic product. Development must also be assessed according to its environmental consequences, social distribution, and long-term resource sustainability. In the context of CPEC, sustainable development requires transportation networks, energy facilities, ports, and industrial projects to generate economic benefits while minimizing pollution, protecting ecosystems, conserving water, and maintaining biodiversity.

The theory is suitable because it provides a framework for evaluating the relationship between immediate development objectives and long-term ecological well-being. It also supports the principle that environmental costs should not be transferred disproportionately to local communities or future generations.

Literature Review

Infrastructure Development and Environmental Change

Infrastructure development under the China–Pakistan Economic Corridor (CPEC) has become an important component of Pakistan's economic growth and regional connectivity. The expansion of highways, transportation networks, energy facilities, industrial zones, and port infrastructure can improve trade, investment, and access to remote areas. However, large-scale infrastructure projects may also create environmental challenges through land-use changes, vegetation clearance, soil erosion, habitat fragmentation, and increased pollution. Munir and Khayyam (2020) argue that economic corridors, including CPEC, may threaten ecological health when infrastructure development is not accompanied by effective environmental protection measures. Therefore, environmental considerations should be

JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal
ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

integrated into project planning, construction, and implementation to minimize ecological damage while achieving development objectives. Transportation and energy infrastructure can generate additional environmental pressures, depending on project design, location, and operational practices. Road construction may disturb natural landscapes and wildlife habitats, while increased traffic can contribute to greenhouse-gas emissions, air pollution, and noise. Similarly, fossil-fuel-based energy projects may increase carbon emissions and local air pollution, whereas hydropower projects can alter river flows and aquatic environments. Khalid et al. (2022) examined the potential environmental consequences of CPEC infrastructure and emphasized the importance of environmental impact assessments and stronger legal safeguards. These concerns demonstrate that infrastructure development should be evaluated not only according to its economic benefits but also according to its environmental costs and long-term implications for Pakistan's ecosystems and natural resources.

Effective environmental governance is essential to reducing the ecological risks associated with CPEC. Project developers and relevant government institutions should conduct comprehensive environmental impact assessments, monitor pollution, protect biodiversity, and implement appropriate mitigation measures throughout the project lifecycle. Waheed et al. (2024) found that environmental governance challenges relevant to CPEC sustainability include weaknesses in environmental law implementation, access to information, coordination, and the participation of marginalized stakeholders. Their findings highlight the importance of transparent decision-making, institutional cooperation, and public engagement in promoting environmentally responsible development. Consequently, Pakistan should strengthen environmental monitoring, incorporate climate-resilient infrastructure planning, and promote sustainable construction practices to ensure that CPEC contributes to economic progress without imposing unnecessary long-term costs on ecosystems and local communities.

CPEC and Environmental Governance

Environmental governance is essential for ensuring that economic development is consistent with environmental protection and sustainable resource management. The China–Pakistan Economic Corridor (CPEC), which includes transportation infrastructure, energy projects, industrial development, and port facilities, presents important opportunities for Pakistan's economic growth while creating potential environmental challenges. Effective environmental governance requires appropriate legislation, institutional coordination, environmental impact assessments, and monitoring mechanisms to identify and manage ecological risks. Munir and Khayyam (2020) argue that economic corridors can threaten ecological health through habitat fragmentation, natural-resource depletion, and other environmental disturbances. Therefore, environmental sustainability should be incorporated into every stage of CPEC project planning and implementation. Pakistan's environmental governance framework faces challenges concerning policy implementation, institutional capacity, transparency, and public participation. Waheed et al. (2024) evaluated environmental governance in Pakistan in the context of CPEC and identified important weaknesses, particularly concerning equity, access to information, and the implementation of environmental laws. These governance challenges may limit the effectiveness of environmental safeguards if regulatory institutions cannot adequately monitor projects or ensure compliance. Similarly, (Khalid et al.2022). Improving environmental governance under CPEC requires a comprehensive approach that combines regulatory enforcement, transparent decision-making, scientific monitoring, and community participation. Federal and provincial

JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal
ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

environmental protection agencies should ensure that environmental impact assessments are conducted before project approval and that mitigation measures are implemented throughout construction and operation. Furthermore, local communities should have opportunities to participate in decisions affecting their water resources, land, forests, and livelihoods. Regular environmental audits and publicly accessible monitoring reports can strengthen accountability and identify emerging ecological risks. Pakistan and China should also promote climate-resilient infrastructure, cleaner energy technologies, and biodiversity-sensitive development planning. These measures can help reconcile economic connectivity with environmental protection and support the long-term sustainability of CPEC (Waheed et al., 2024).

Water Resources and Development

Water is central to Pakistan's economy, agriculture, energy systems, and public health. Rivers originating in the Hindu Kush–Karakoram–Himalayan region contribute to the Indus River system, which supports extensive irrigation networks and urban water supplies. Pakistan's dependence on climate-sensitive water resources makes water governance an important consideration for major infrastructure and energy projects. Construction activities can affect water quality through sediment runoff, excavation, improper disposal of waste, and accidental releases of fuel or chemicals. Energy projects may require water for construction, cooling, processing, or other operational purposes, depending on their design. Hydropower development can modify river flow regimes, sediment transport, and aquatic habitats. Industrial and urban development can increase demand for freshwater and create additional wastewater-management requirements (Aslam. et, al, 2023).

The Intergovernmental Panel on Climate Change (IPCC) has highlighted the vulnerability of mountain regions and water systems to climate change. In Pakistan, these concerns interact with changing precipitation patterns, glacier dynamics, extreme floods, and periods of water scarcity. CPEC projects must therefore be evaluated within a broader context of climate risk, watershed management, and competing demands for water.

Biodiversity and Habitat Conservation

Biodiversity encompasses the variety of genes, species, and ecosystems that sustain ecological functioning and human livelihoods. Pakistan contains important mountain, forest, grassland, desert, wetland, riverine, and marine habitats. These environments support wildlife, plants, fisheries, pollinators, and other species that contribute to ecological stability and economic activity. Infrastructure can affect biodiversity through habitat loss, fragmentation, disturbance, pollution, and barriers to wildlife movement. Roads may divide habitats into smaller areas and increase the likelihood of wildlife collisions. Industrial development may reduce or alter habitat availability, while poorly managed tourism and settlement expansion can increase pressure on sensitive environments. Construction near rivers and wetlands can affect aquatic species through sedimentation and changes in water quality.

The Convention on Biological Diversity and the International Union for Conservation of Nature emphasize the importance of habitat protection, ecological connectivity, and the conservation of threatened species. Applying these principles to CPEC requires location-specific ecological surveys, biodiversity-sensitive route planning, avoidance of critical habitats, and monitoring before and after construction.

Analysis and Discussion

CPEC and Ecosystem Change in Pakistan

The China–Pakistan Economic Corridor (CPEC) has significant implications for Pakistan's ecosystems because its transportation networks, energy projects, industrial zones, and associated infrastructure interact with diverse natural environments. Infrastructure development can contribute to vegetation clearance, soil erosion,

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ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

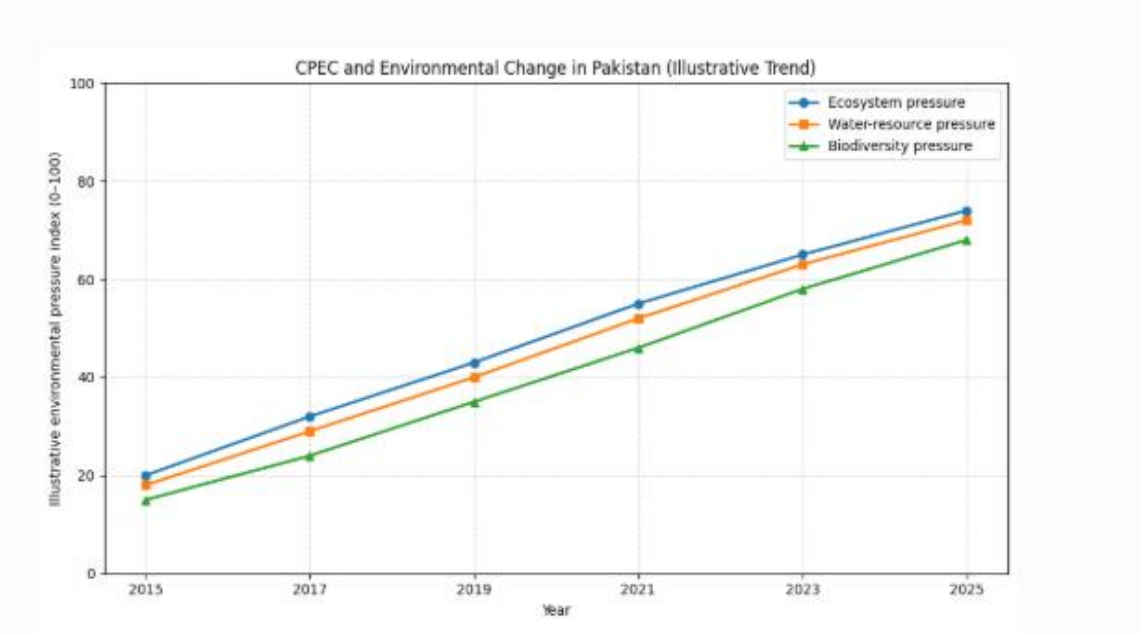
habitat fragmentation, and changes in land-use patterns. Munir and Khayyam (2020) argue that economic corridors can create serious risks for ecological health, wildlife habitats, and natural-resource conservation when environmental protection is not adequately incorporated into development planning. Although CPEC can improve connectivity and economic opportunities, its environmental consequences depend on project locations, construction practices, and the effectiveness of mitigation measures. Therefore, environmental assessments should identify sensitive ecosystems before construction begins and recommend appropriate measures to minimize ecological disturbance (Khayyam, 2020).

The potential effects of CPEC on Pakistan's ecosystems are closely connected to water-resource management, climate change, and biodiversity conservation. Road construction and excavation may increase sediment runoff into rivers, while industrial activities and inadequate waste disposal can contribute to water pollution. Similarly, infrastructure expansion may disturb wildlife habitats and interrupt ecological connectivity, particularly in environmentally Sensitive Mountain and coastal areas. Khalid et al. (2022) identify coal-fired power generation, vegetation clearance, and increased transportation activity as important environmental concerns associated with CPEC development. These risks demonstrate the importance of assessing how individual projects interact with existing environmental pressures. However, the extent of actual damage must be established through reliable project-specific evidence, including environmental assessments, water-quality monitoring, and biodiversity surveys.

Protecting Pakistan's ecosystems requires a development strategy that integrates environmental sustainability into CPEC planning and implementation. Ali and Askari (2023) highlight the environmental risks associated with CPEC projects and emphasize the importance of protecting Pakistan's natural environment. Effective measures include strengthening environmental impact assessments, preventing unnecessary deforestation, rehabilitating disturbed land, protecting wildlife corridors, and establishing long-term environmental monitoring systems. Particular attention should be given to the fragile mountain ecosystems of Gilgit-Baltistan and the water-scarce coastal environment around Gwadar, where ecological conditions and community needs differ considerably. Cooperation between federal and provincial institutions, project developers, environmental experts, and local communities can improve environmental accountability. Such measures can help Pakistan pursue economic development while conserving ecosystems and natural resources for future generations (Khalid et al.2022).

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Volume 4 • Issue 6 • October 2026



Line Graph: CPEC and Environmental Change in Pakistan (2015–2025)

Overview

The line graph titled CPEC and Environmental Change in Pakistan (2015–2025) illustrates the potential environmental pressures associated with infrastructure development under the China–Pakistan Economic Corridor (CPEC). It presents three dimensions: ecosystem pressure, water-resource pressure, and biodiversity pressure. The illustrative trends show a gradual increase in all three dimensions over the selected period, highlighting environmental issues that may require attention alongside economic development.

The ecosystem-pressure line shows the highest illustrative index, rising from 20 in 2015 to 74 in 2025. This represents potential concerns associated with road construction, land-use changes, habitat fragmentation, and infrastructure expansion. The water-resource-pressure line increases from 18 to 72, emphasizing the importance of assessing water availability, construction-related pollution, and pressures on local water systems. Meanwhile, biodiversity pressure rises from 15 to 68, illustrating possible risks to wildlife habitats, vegetation, and ecological balance. Overall, the graph emphasizes the importance of integrating environmental protection into CPEC planning and implementation. Environmental impact assessments, effective monitoring, sustainable water management, habitat conservation, and stronger environmental governance can help reduce the potential negative consequences of infrastructure development. Important methodological note: These figures are conceptual illustrations, not verified measurements of CPEC's environmental impacts. They should not be interpreted as evidence that CPEC caused the increases. For a research paper, the graph should ideally be replaced with empirical data from environmental assessments, government reports, and peer-reviewed studies.

Impacts on Water Resources

Water resources are a central component of Pakistan's environmental security. The Indus River system supports agriculture, hydropower, drinking-water supplies, and numerous ecological functions. Infrastructure development can influence this system through construction runoff,

JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal
ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

water withdrawals, changes in drainage, industrial wastewater, and modifications to river flow or sediment transport. During road construction, exposed soil and excavated material may enter nearby streams if erosion-control measures are inadequate. Construction camps and machinery can generate sewage, solid waste, oils, and other pollutants. These risks can be reduced through proper drainage, wastewater treatment, designated waste-disposal sites, fuel-storage controls, and routine water-quality monitoring. The Energy projects require different forms of water management depending on their technology. Hydropower facilities can alter the timing and distribution of river flows, affect sediment movement, and change aquatic habitats. Thermal power plants may require water for cooling and other operations, depending on the system employed. Wind and solar power generally have lower operational water requirements than many conventional thermal technologies, although construction, panel cleaning, manufacturing, and land-use choices can still produce environmental effects (Awan, et, al, 2025).

Consequently, an assessment of CPEC's water footprint should distinguish among project types rather than treating all energy projects as environmentally equivalent. Industrial estates and new settlements may increase demand for freshwater in locations where supplies are already constrained. This is particularly relevant in arid and semi-arid regions, including parts of Baluchistan. Without adequate planning, rising demand can intensify competition among households, agriculture, industry, and ecological needs. Groundwater extraction may also become unsustainable if withdrawals exceed replenishment. Climate change further complicates water-resource management. Changes in precipitation, glacier conditions, snowmelt, and extreme weather can affect the timing and reliability of water supplies. Pakistan's mountain watersheds are especially important because they contribute to the wider Indus system. Infrastructure planning should therefore incorporate climate projections, flood-risk assessments, watershed protection, and emergency preparedness.An integrated water-management approach is necessary to reduce these risks. Projects should assess their water requirements before approval, identify the likely effects on local users and aquatic environments, and establish measurable standards for water quality and wastewater treatment. Public reporting of water withdrawals, pollution incidents, and compliance with environmental conditions would improve transparency and accountability.

Implications for Biodiversity

Biodiversity is essential for ecosystem resilience, agricultural productivity, ecological balance, and human well-being. Pakistan's varied geography supports numerous plant and animal species, including wildlife associated with mountain habitats, forests, wetlands, deserts, rivers, and coastal ecosystems. Infrastructure expansion can threaten biodiversity when it reduces habitat availability, interrupts wildlife movement, or increases human disturbance. Habitat fragmentation is a major potential concern associated with roads and other linear infrastructure. When continuous habitats are divided into smaller areas, wildlife populations may become isolated and less able to access food, water, breeding grounds, and seasonal migration routes. Roads can also increase wildlife mortality, introduce noise and artificial light, and facilitate access to previously remote habitats (Ali, et,al 2024).

In mountain regions, biodiversity concerns should be considered alongside the protection of alpine ecosystems, forests, and river corridors. Construction near wildlife habitats may alter vegetation and disturb animal movement, while increased traffic and tourism can create additional pressures. These risks can be reduced through ecological surveys, route adjustments, speed controls in wildlife-sensitive areas, carefully designed crossing structures where appropriate, and restrictions on construction during sensitive

JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal
ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

breeding periods. In coastal Baluchistan, the development of ports and associated urban infrastructure requires attention to marine and coastal habitats. Potential issues include disturbance associated with construction and dredging, changes to shoreline processes, wastewater discharge, and the management of solid waste. The actual effects depend on the location, scale, and design of each project and should be established through marine and coastal environmental assessments.

Climate Change and Environmental Vulnerability

Climate change is an important contextual factor in assessing the environmental sustainability of CPEC. Pakistan faces risks associated with extreme rainfall, floods, heatwaves, droughts, and changes in water availability. Mountain regions face additional challenges linked to glacier change, slope instability, and glacial lake outburst flood hazards. These conditions can affect infrastructure, ecosystems, and local communities simultaneously. CPEC infrastructure may be exposed to floods, landslides, rock falls, extreme temperatures, and changing patterns of precipitation. If climate risks are not adequately considered during planning and construction, roads, bridges, power facilities, and associated services may experience repeated damage, increasing repair costs and disrupting economic activity. Infrastructure failure can also create secondary environmental effects through debris, erosion, and the release of stored pollutants (Hassan, et,al, 2024).

Climate-resilient planning requires hazard mapping, updated engineering standards, effective drainage, slope stabilization, protection of river corridors, and emergency-response systems. Infrastructure assessments should consider future climatic conditions rather than relying exclusively on historical weather patterns. In mountainous regions, climate and geological risks should be assessed together because rainfall, snowmelt, slope conditions, and land disturbance can interact. The climate implications of energy development also require careful evaluation. Fossil-fuel-based generation can increase greenhouse-gas emissions, while renewable-energy projects may support emissions reduction when they displace more carbon-intensive generation. Nevertheless, the full environmental performance of energy projects depends on their design, lifecycle emissions, land-use impacts, and effects on water and biodiversity. A sustainable CPEC strategy should therefore consider both climate mitigation and adaptation.

Environmental Governance and Institutional Challenges

The effectiveness of environmental protection depends on the institutions responsible for assessment, approval, monitoring, enforcement, and public accountability. Pakistan has environmental legislation and regulatory institutions, but implementation can be complicated by limited monitoring capacity, fragmented responsibilities, data gaps, and competing development priorities. Environmental impact assessment is a central mechanism for identifying risks before projects are approved. However, an assessment is useful only if it is based on reliable baseline information, evaluates realistic alternatives, identifies cumulative impacts, and leads to enforceable mitigation measures. If monitoring after approval is weak, environmental commitments may not be implemented consistently throughout construction and operation (Lashari, 2024).

Coordination is particularly important when infrastructure crosses provincial boundaries or affects shared watersheds. Federal and provincial authorities may have different responsibilities, while local administrations and communities possess knowledge about seasonal water use, wildlife movement, and environmental changes that may not be reflected in national planning documents. Clear institutional responsibilities and accessible reporting mechanisms can help bridge these gaps. Public participation can also improve environmental outcomes. Local

JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

communities often experience the immediate effects of construction, changes in resource access, and pollution. Consultation should therefore take place early enough to influence project design, rather than merely informing residents after major decisions have been made. Publicly accessible environmental assessments, monitoring results, and grievance procedures can strengthen trust and make it easier to identify problems before they become severe (Saeed. et, al, 2023).

CPEC's environmental performance should ultimately be assessed through measurable outcomes, including compliance with environmental conditions, changes in water quality, habitat disturbance, waste-management performance, emissions, and the effectiveness of restoration measures. Transparent reporting would make it possible to compare predicted impacts with actual environmental conditions and improve future project planning.

Conclusion

The China–Pakistan Economic Corridor (CPEC) represents a significant initiative for Pakistan's economic development, regional connectivity, energy production, and industrial growth. However, its long-term success depends not only on economic benefits but also on its environmental sustainability. This study examined the potential and documented environmental implications of CPEC, focusing on ecosystem change, water resources, and biodiversity. The analysis indicates that infrastructure construction, energy development, industrial expansion, and associated urbanization can create environmental pressures through habitat fragmentation, vegetation clearance, soil erosion, water pollution, and increased demand for natural resources. Nevertheless, the nature and severity of these impacts vary according to project design, geographical location, and the effectiveness of environmental safeguards.

The importance of protecting Pakistan's diverse ecological landscapes, including the fragile mountain ecosystems of Gilgit-Baltistan, the agricultural regions of Punjab and Sindh, and the coastal environment surrounding Gwadar. Water-resource management and biodiversity conservation are particularly important because environmental degradation can affect local livelihoods, agricultural productivity, public health, and ecological stability. Climate change further increases these challenges by intensifying risks associated with floods, droughts, extreme temperatures, and changing water availability. Therefore, environmental impact assessments, climate-resilient infrastructure, integrated water management, and biodiversity-sensitive planning should be incorporated into every stage of CPEC project development.

The economic development and environmental protection should be treated as complementary objectives rather than competing priorities. Pakistan and China should strengthen environmental regulations, improve coordination between federal and provincial institutions, enhance public participation, and establish transparent monitoring systems to evaluate environmental performance. Project developers should also prioritize pollution prevention, habitat conservation, responsible waste management, and the restoration of environmentally disturbed areas. Sustainable Development Theory provides an important foundation for ensuring that present economic benefits do not compromise the needs of future generations. By integrating environmental governance into CPEC planning and implementation, Pakistan can strengthen the corridor's contribution to sustainable development while protecting its ecosystems, water resources, biodiversity, and natural heritage.

Policy Recommendations

Strengthen Environmental Impact Assessments

The Government of Pakistan should strengthen environmental impact assessments (EIAs) for all CPEC-related infrastructure, energy, industrial, and port development projects. Assessments should be conducted before project approval and

JOURNAL FOR SOCIAL SCIENCE STUDIES
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Volume 4 • Issue 6 • October 2026

should examine potential impacts on ecosystems, water resources, biodiversity, and local communities. Independent environmental reviews and regular compliance inspections should be introduced to ensure that project developers implement the recommended mitigation measures. Strategic environmental assessments should also be used to identify the cumulative environmental consequences of multiple projects within the same region.

Protect Ecosystems and Natural Habitats

CPEC development should prioritize the protection of ecologically sensitive areas, including mountain ecosystems, forests, wetlands, river corridors, and coastal habitats. Infrastructure routes should be planned to avoid critical wildlife habitats and minimize unnecessary vegetation clearance. Where environmental disturbance cannot be avoided, developers should implement habitat restoration, erosion control, and ecological rehabilitation measures. Particular attention should be given to the fragile mountain environments of Gilgit-Baltistan and the coastal ecosystems surrounding Gwadar, where development planning must reflect local ecological conditions.

Improve Water-Resource Management

Pakistan should introduce comprehensive water-management plans for CPEC projects to reduce pressure on freshwater resources and prevent water pollution. Project developers should assess water requirements before construction and establish appropriate systems for wastewater treatment, sediment control, and the safe disposal of construction waste. Industrial and energy projects should adopt water-efficient technologies wherever feasible. Regular monitoring of river water, groundwater, and wastewater quality should be conducted, and monitoring results should be made publicly accessible. These measures are particularly important in water-scarce regions where communities, agriculture, industry, and ecosystems depend on limited supplies.

Promote Biodiversity Conservation

Biodiversity protection should be integrated into the planning and implementation of all CPEC projects. Environmental assessments should identify threatened species, wildlife migration routes, breeding habitats, and ecologically important areas before construction begins. Where necessary, project designs should incorporate wildlife crossings, habitat corridors, and restrictions on construction activities during sensitive ecological periods. Relevant environmental agencies should cooperate with research institutions and conservation organizations to monitor changes in biodiversity. Development projects should avoid irreversible damage to critical habitats and ensure that mitigation measures are properly funded and evaluated.

Strengthen Environmental Governance and Institutional Coordination

The federal and provincial governments should improve coordination among planning authorities, environmental protection agencies, local administrations, and CPEC project developers. Clear institutional responsibilities should be established for environmental assessment, regulatory approval, inspection, and enforcement.

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JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

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