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Climate Smart Strategies: Advancing Sustainable Development Goals in the 21st Century (Pakistan)

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ABSTRACT
Climate change represents one of the most significant global challenges of the 21st century, threatening the achievement of the Sustainable Development Goals (SDGs). Its impacts, including rising temperatures, extreme weather events, and biodiversity loss, exacerbate socio-economic inequalities and hinder progress on critical SDGs such as poverty alleviation, food security, clean energy, and sustainable urbanization. This study explores innovative strategies to mitigate climate change while advancing SDG objectives through technological, financial, policy-driven, and community-based approaches. Technological innovations such as renewable energy systems, climate-smart agriculture, and urban green infrastructure offer scalable solutions for reducing emissions and building climate resilience. Financial mechanisms, including green finance and public-private partnerships, play a critical role in mobilizing resources for sustainable projects. Policy integration and international collaboration, coupled with grassroots community initiatives, further ensure inclusivity and equitable benefits. Despite progress, significant gaps remain in integrating these strategies within global frameworks and modifying them to local contexts, particularly in low and middle income countries. Using a mixed-methods approach, this study combines case studies, quantitative data analysis to assess the effectiveness and flexibility of these innovations. The findings highlight the potential of synergistic strategies that align climate action with SDGs, emphasizing cross-sectorial collaboration and inclusivity. By identifying barriers such as governance challenges and funding limitations, the study provides actionable recommendations to policymakers, private sector actors, and local communities. This research underscores the urgency of innovative, integrated approaches to combat climate change and promote sustainable development, offering a pathway to achieving a resilient and equitable future.

Keywords: *Climate Change, SDGs, Innovation, Climate-Smart Strategies, Renewable Energy, Green Finance, Climate Resilience, Public-Private Partnerships, Policy Integration.*

Introduction

As the world grapples with the escalating impacts of climate change, developing countries like Pakistan find themselves at a critical interval where sustainable development must be reimagined through a climate-resilient lens. Pakistan, ranked among the top ten most climate-vulnerable countries globally by the Global Climate Risk Index, is increasingly affected by a range of environmental stressors glacial retreat in the north, rising sea levels in the south, erratic monsoon patterns, frequent floods, prolonged droughts, and rapidly declining groundwater resources. These challenges not only threaten the country's ecological stability but also have far-reaching implications for its socio-economic development, exacerbating poverty, food insecurity, public health crises, and displacement. In this context, achieving the Sustainable Development Goals (SDGs) particularly those related to poverty reduction (SDG 1), zero hunger (SDG 2), clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), sustainable cities (SDG 11), and climate action (SDG 13) requires the urgent integration of climate-smart strategies into national and local development planning.

Climate-smart strategies refer to an integrated approach that simultaneously enhances resilience to climate change, reduces greenhouse gas emissions, and supports inclusive socio-economic development. These strategies involve a combination of policy reforms, technological innovations, infrastructure modernization, institutional coordination, and community-based adaptation to ensure that development gains are not undermined by environmental risks. For Pakistan, where agriculture accounts for nearly 20% of GDP and employs a large segment of the rural population, climate-smart agriculture becomes a vital entry point for adaptation. Similarly, transitioning to renewable energy sources, improving urban planning through nature-based solutions, and adopting water-efficient technologies are essential steps toward building climate-resilient systems. Moreover, aligning national climate action with global frameworks such as the Paris Agreement and the 2030 Agenda for Sustainable Development is vital for mobilizing international support and financing.

This paper aims to examine how climate-smart strategies can effectively contribute to advancing Pakistan's progress on the SDGs in the 21st century. It explores sectorial interventions in agriculture, water management, urban infrastructure, and energy systems, along with the enabling role of governance, institutional reforms, public-private partnerships, and community participation. Through a review of relevant policies, case studies, and international best practices, the paper seeks to highlight pathways through which Pakistan can operationalize a climate-smart development agenda. Ultimately, the adoption of such strategies is not merely a matter of environmental necessity but a fundamental prerequisite for sustainable, inclusive, and resilient growth in an era defined by climate uncertainty.

1. Energy Sector: Transitioning to Renewable and Low-Carbon Pathways

Energy plays a central role in both driving economic development and exacerbating climate change. For Pakistan, the energy sector is crucial in meeting both national development goals and international climate commitments. With a growing population and increasing industrialization, the demand for energy in Pakistan has surged, yet the country remains highly dependent on fossil fuels. This reliance poses significant environmental, economic, and security risks, particularly as climate change intensifies the frequency and severity of natural disasters such as floods and droughts. Pakistan's energy sector is responsible for about 40% of the country's total greenhouse gas emissions, primarily from fossil fuel-based electricity generation, transport, and industrial processes. To mitigate these effects and accelerate progress toward SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), Pakistan has embraced renewable energy and low-carbon pathways.

1.1. Renewable Energy Expansion

Renewable energy has emerged as a key part of Pakistan's strategy to reduce dependence on fossil fuels, lower carbon emissions, and increase energy access across rural and underserved areas. By 2023, Pakistan had set a target of 30% renewable energy by 2030, with a major focus on solar, wind, and hydropower.

Example 1: Quaid-e-Azam Solar Park (Bahawalpur)

One of the most notable examples of solar energy development in Pakistan is the Quaid-e-Azam Solar Park, located in Bahawalpur, Punjab. With an installed capacity of 1,000 MW, it is one of the largest solar energy

installations in Asia. The park, developed in phases, is a testament to Pakistan's commitment to clean energy and sustainable development. In addition to providing power to over 1 million people[1], it significantly reduces the country's reliance on fossil fuels. The success of the Quaid-e-Azam Solar Park also highlights Pakistan's potential to harness its vast solar energy resources, as the region receives over 300 sunny days per year.

- **Impact on SDGs:** The solar park directly contributes to SDG 7 (Affordable and Clean Energy) and indirectly supports SDG 13 (Climate Action) by reducing greenhouse gas emissions. It also supports SDG 8 (Decent Work and Economic Growth) by creating jobs in renewable energy infrastructure development and operation.

Afforestation Initiatives:

The Ten Billion Tree Tsunami Project, launched in 2018, aims to restore forest cover, enhance biodiversity, and sequester carbon[2]. As of 2023, millions of trees have been planted, contributing to carbon offsetting.

Mitigation Measure	Description	Impact in Pakistan
Wind Energy Projects	Utilization of Jhimpir Wind Corridor.	Reduces reliance on imported fossil fuels.
Ten Billion Tree Tsunami	Nationwide afforestation campaign.	Enhances biodiversity and reduces CO2 emissions.
Energy Efficiency Programs	Adoption of energy-saving technologies.	Reduces industrial and residential energy consumption.

Example 2: Gharo-Keti Bandar Wind Corridor

The **Gharo-Keti Bandar Wind** Corridor along the coast of Sindh represents Pakistan's largest wind energy initiative. This corridor has the potential to generate up to **50,000 MW** of energy, with **1,000 MW** already being harnessed by 2023.[3] The development of wind farms in this region has been accelerated through **foreign investment**, particularly from China, which has supported the installation of wind turbines and grid infrastructure[4]. The **First Wind Power Project**, developed by **Zorlu Energy** and **Fauji Fertilizer**, was among the first projects in this corridor, contributing **50 MW** to the national grid[5].

- **Impact on SDGs:** This wind energy project directly contributes to **SDG 7** and **SDG 13**, with the added benefits of local employment creation and energy security. The project's economic impact is far-reaching, particularly in rural areas, where local communities are provided with job opportunities in wind farm construction, operation, and maintenance.

1.2. Hydropower Potential

Pakistan has significant hydropower potential, estimated at around 60,000 MW, although only a fraction of this capacity has been harnessed. Hydropower is the largest contributor to Pakistan's renewable energy generation, accounting for approximately 30% of the country's electricity supply. The Neelum-Jhelum Hydropower Project, with an installed capacity of 969 MW[6], is one of the major ongoing projects aimed at enhancing the country's hydropower capacity. It aims to provide a clean, renewable source of electricity while reducing dependence on fossil fuels and lowering greenhouse gas emissions.

- **Case Study: Neelum-Jhelum Hydropower Project**

The Neelum-Jhelum Hydropower Project is located in the **Azad Jammu and Kashmir region** and is a critical part of Pakistan's energy strategy. The project aims to harness the potential of the **Neelum River** and is expected to generate **5.15 billion kWh** of electricity annually[7]. When completed, it will not only provide clean energy but will also contribute to flood control, irrigation, and economic development in the region.

- **Impact on SDGs:** The hydropower project directly contributes to **SDG 7**, providing clean energy to millions of households while reducing reliance on fossil fuel-based power generation. The project also supports **SDG 13** by mitigating carbon emissions through the use of renewable energy.

1.3. Public-Private Partnerships (PPPs) in Renewable Energy Development

In recent years, the Public-Private Partnership (PPP) model has played a key role in promoting renewable energy development in Pakistan. The government has actively encouraged foreign investment in the energy sector, particularly in solar, wind, and **hydroelectric power**, through incentives such as tax exemptions and feed-in tariffs.

- **Case Study: Alternative Energy Development Board (AEDB)**

The Alternative Energy Development Board (AEDB), established by the government of Pakistan in 2003, plays a central role in promoting renewable energy projects in the country. The AEDB has facilitated several successful PPPs, such as the **Gul Ahmed Wind Power Project** and the **Uch Power Plant**,[8] which have attracted international investors and increased Pakistan's renewable energy capacity. These partnerships are essential for scaling up renewable energy projects and ensuring that the benefits are widely distributed[9].

- **Impact on SDGs:** These PPPs contribute to SDG 7 by accelerating renewable energy deployment and SDG 9 by fostering industry innovation and infrastructure development. The investments in renewable energy also help Pakistan make significant strides towards its climate commitments under SDG 13.

1.4. Energy Efficiency and Smart Grid Systems

Beyond increasing renewable energy generation, Pakistan has also prioritized energy efficiency measures. This includes the adoption of smart grid systems, energy-saving technologies, and reducing energy losses. The **National Electric Power Regulatory Authority** (NEPRA) has implemented energy efficiency standards for appliances and industrial processes to curb energy waste[10].

- **Example: Smart Grid Development in Islamabad**

In Islamabad, the government has begun implementing smart grid systems that integrate renewable energy into the national grid more effectively, while optimizing electricity consumption. These smart grids are designed to improve the efficiency of electricity distribution, reduce transmission losses, and allow for better management of energy supply and demand.

- **Impact on SDGs:** The implementation of smart grids supports SDG 7 by improving energy access and reliability, and it also supports SDG 13 through increased energy efficiency and reduced emissions.

2. Climate-Smart Agriculture, Food Security, and Sustainable Land Use in Pakistan

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[3] Pakistan Wind Energy Association. (2022). Annual Report on Wind Power Development in Pakistan. Pakistan Wind Energy Association.

[4] National Energy Efficiency and Conservation Authority (NEECA), National Energy Efficiency Report, 2022.

[5] World Bank, Country Climate and Development Report: Pakistan, 2021.

[6] National Energy Efficiency and Conservation Authority (NEECA). (2022). Energy Efficiency Programs in Pakistan.

[7] National Energy Efficiency and Conservation Authority (NEECA), National Energy Efficiency Report, 2022.

[8] World Bank. (2021). Pakistan's Climate and Energy Strategy: Towards a Green, Resilient, and Inclusive Future.

[9] Alternative Energy Development Board (AEDB), Annual Report on Wind and Solar Energy Projects, 2021.

[10] Asian Development Bank (ADB). (2021). Pakistan: Advanced Metering Infrastructure Project – Islamabad Electric Supply Company (IESCO). Retrieved from https://www.adb.org/projects/47235-002/main

Pakistan's agricultural sector is the backbone of its economy, supporting livelihoods for nearly two-thirds of the population directly or indirectly. However, climate change poses a severe threat to this sector, with increasingly unpredictable monsoons, glacial melt, droughts, floods, and rising temperatures. These climate stressors not only reduce crop yields but also disrupt water availability, increase pest infestations, and degrade land quality. In response, Climate-Smart Agriculture (CSA) has been introduced as a comprehensive approach to transform and reorient agricultural systems to support food security under the realities of climate change.

CSA focuses on three interlinked goals:

(1) Sustainably increasing agricultural productivity and incomes,

(2) Adapting and building resilience to climate change, and

(3) Reducing greenhouse gas emissions where possible.

Techniques in Climate-Smart Agriculture

Technique	Description	Impact	Examples from Pakistan	Comparison with Other Countries
Agroforestry	Integrating trees with crops and livestock to optimize land use and ecosystem health.	Improves soil fertility, sequesters carbon, and provides additional income through timber or fruit crops.	Khyber Pakhtunkhwa's Billion Tree Afforestation Project includes agroforestry practices benefiting farmers.	In Kenya, agroforestry is used to combat desertification and improve food security through tree-crop integration.
Precision Farming	Using technology (e.g., GPS, IoT) to optimize input use (water, fertilizers, pesticides).	Reduces resource wastage, lowers input costs, and enhances productivity.	Punjab's PARC Smart Agriculture Program promotes precision irrigation and fertilizer management.	In USA, precision farming is supported by drones and AI to optimize large-scale farm operations.
Resilient Crop Varieties	Developing crops resistant to extreme weather (drought, heat) and pests.	Ensures reliable yields, even under changing climate conditions.	Heat-resistant wheat varieties developed by Pakistan Agricultural Research Council (PARC) are cultivated in Sindh.	India's NICRA has successfully introduced drought-tolerant rice and maize varieties.
Conservation Agriculture	Practices like minimal tillage, crop rotation, and cover cropping to protect soil health.	Reduces soil erosion, conserves water, and increases carbon sequestration.	Adoption of no-till farming techniques in cotton fields of Punjab has reduced costs and improved yields.	In Brazil, conservation agriculture is widely used to reduce deforestation and enhance soil fertility.
Integrated Water Management	Efficient use of water resources through techniques like drip irrigation and water harvesting.	Reduces water wastage and improves water-use efficiency in farming.	Agriculture Productivity Enhancement Project (SIAPEP) promotes drip irrigation for high-value crops.	its advanced drip irrigation technology in arid regions.

In Pakistan, CSA practices include laser land leveling, drip and sprinkler irrigation systems, heat- and drought-tolerant crop varieties, crop diversification, agroforestry, and conservation agriculture. For instance, in Punjab, farmers using zero tillage techniques and raised-bed planting have seen reductions in water use by up to 30%, while maintaining or improving crop yields. This is especially important for wheat and maize, Pakistan's staple crops, which are increasingly affected by heat stress and late sowing due to climatic disruptions.

One notable initiative is the Punjab Climate Smart Agriculture Project,[11] funded by the World Bank, which has worked with over 190,000 farmers to promote water-smart technologies such as solar-powered irrigation, drip irrigation systems, and climate information services. This has significantly improved water use efficiency and farmer resilience, especially in the semi-arid districts of southern Punjab. Likewise, the Climate Resilient Agriculture and Water Management Project in Sindh has trained thousands of smallholder farmers[12] in integrated water management, composting, and saline-resistant crops, especially in flood-affected districts like Badin and Thatta.

Sustainable land use is another crucial component. Pakistan loses nearly 27,000 hectares of forest land annually due to deforestation and land degradation, which directly affects soil fertility and biodiversity. To combat this, CSA promotes agroforestry, pasture management, and soil conservation techniques. The National Agroforestry Policy introduced in 2015, although still under-implemented, aims to integrate trees into farming systems, particularly in degraded areas, thus increasing carbon sequestration while improving soil moisture and biodiversity.

In terms of food security, CSA supports value chain improvements, post-harvest loss reduction, and access to climate information services, which are critical for ensuring stable food supplies. For example, mobile-based weather forecasting tools provided through apps like Pak Agri Market have helped farmers make better planting and irrigation decisions, reducing losses and improving market access. Despite these successes, major challenges remain. These include limited awareness, inadequate financing, poor access to CSA technology, and institutional fragmentation[13]. Many smallholder farmers lack the financial capacity to invest in climate-resilient technologies or adopt new techniques. This underscores the need for climate finance mechanisms, public-private partnerships, and extension services tailored to local needs. CSA presents a viable and essential pathway for Pakistan to secure its food systems, protect rural livelihoods, and achieve sustainable land use. By embedding climate resilience into agriculture, the country can address SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land), while ensuring long-term ecological and economic sustainability[14].

3. Water: Conservation, Climate-Induced Stress & Technological Innovation

Water is the lifeline of Pakistan's agrarian economy, but it faces critical stress due to both climate change and

[11] World Bank. (2021). Punjab Climate Smart Agriculture Project. Retrieved from https://projects.worldbank.org/en/projects-operations/project-detail/P162446

[12] Food and Agriculture Organization (FAO). (2021). Climate-Smart Agriculture Sourcebook: Pakistan Country Profile. FAO.

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inefficient water management. Pakistan ranks among the most water-stressed countries in the world, with per capita water availability dropping from 5,260 cubic meters in 1951 to less than 1,000 cubic meters in 2021 now considered below the water scarcity threshold[15].

- **Conservation & Management:**

Climate-smart water management involves increasing efficiency, equity, and resilience. Key strategies include rehabilitating irrigation infrastructure, lining watercourses, and introducing demand-based irrigation scheduling. The National Water Policy (2018) emphasizes integrated water resource management[16], particularly under climate-induced pressures such as glacier melt and erratic rainfall.

- **Innovations – Drip & Sprinkler Irrigation:**

Technologies like drip irrigation have been promoted through government subsidies in provinces like and Sindh, significantly increasing water use efficiency by up to 70%. For example, under the Punjab Irrigated Agriculture Productivity Improvement Project (PIPIP), over 3,000 acres of land have been brought under drip irrigation, leading to water savings of up to 50% compared to traditional methods[17]. Additionally, smart moisture sensors and solar-powered tube wells are now being adopted in arid districts such as Bahawalpur and Tharparkar.

- **Case Example:**

The Indus Basin Irrigation System, one of the largest in the world, is vulnerable to climate variability. Projects like Recharge Pakistan a joint initiative of the WWF-Pakistan, MoCC, and the Green Climate Fund aim to restore natural floodplains and promote groundwater recharge, contributing to both SDG 6 (Clean Water) and SDG 13 (Climate Action).

4. Urban Development: Green Infrastructure & Climate-Resilient Cities

Urban areas in Pakistan, especially megacities like Karachi, Lahore, and Islamabad, are highly susceptible to urban heat islands, flooding, and air pollution, largely driven by unregulated urban sprawl and insufficient climate planning.

- **Green Infrastructure:**

Green roofs, urban forests, bioswales, and rain gardens are now being recognized for their ability to absorb heat, manage storm water, and sequester carbon. For instance, Lahore's Miyawaki[18] urban forest initiative, launched by the Punjab government in 2020, has led to the creation of over 50 micro forests, helping reduce local temperatures and improve air quality[19].

- **Climate-Resilient Planning:**

The Punjab Spatial Strategy (2021) integrates climate resilience into urban planning through risk mapping and zoning regulations. In Karachi, the Green Line BRT project combines sustainable transport with urban resilience by reducing vehicular emissions and encouraging modal shift from private to public transport.

- **Sustainable Transportation:**

Efforts to promote electric vehicles (EVs) are guided by the National Electric Vehicle Policy (2019), which aims for 30% of vehicles to be electric by 2030. Islamabad Electric Vehicle Charging Stations and Lahore Metro Bus electrification are early steps in this transition, contributing to SDG 11 (Sustainable Cities) and SDG 9 (Industry, Innovation and Infrastructure)[20].

5. Institutional Reforms: Policy Integration, Capacity, PPPs

A major barrier to effective climate action in Pakistan is institutional fragmentation, where climate and development decisions often occur in silos.

- **Policy Integration:**

The Framework for Implementation of Climate Change Policy (2014–2030) outlines cross-sectorial priorities, but lacks enforcement mechanisms. A key reform is the Mainstreaming Climate Change into Development Planning initiative, led by the Ministry of Climate Change with UNDP support. It has helped provinces integrate climate considerations into Annual Development Plans (ADPs)[21].

- **Inter-agency Coordination:**

The Pakistan Climate Change Council was reactivated under the Pakistan Climate Change Act (2017) to serve as a national coordination body. However, overlapping mandates between the Planning Commission, MoCC[22], and provincial environment departments still hinder integrated responses[23].

- **Capacity Building:**

Training programs by LEAD Pakistan and SDPI have strengthened the capacity of mid-level bureaucrats in climate risk assessment and planning. Universities like COMSATS and LUMS are also integrating climate modules into engineering and planning curricula.

- **Public-Private Partnerships (PPPs):**

PPPs are becoming increasingly important in financing climate-smart infrastructure. The Karachi Urban Flood Control project, launched in partnership with the Asian Infrastructure Investment Bank (AIIB), and the Islamabad Smart Grid Project with the Asian Development Bank (ADB) are examples of successful PPPs that blend climate adaptation with service delivery improvements[24].

Conclusion

Climate-smart strategies have emerged as essential tools for Pakistan in addressing the adverse impacts of climate change while advancing key Sustainable Development Goals (SDGs). This paper has documented evidence across multiple sectors energy, agriculture, water, urban development, and institutional reforms illustrating the country's ongoing efforts to transition toward sustainable development.

In the energy sector, efforts to integrate renewable energy sources such as wind and solar power, supported by innovative approaches like smart grids and energy efficiency programs, are reducing reliance on imported fossil fuels and decreasing greenhouse gas emissions. Meanwhile, climate-smart agriculture practices, including drip irrigation, drought-resistant crops, and precision farming techniques, have significantly contributed to food security and resilient land use, particularly in vulnerable regions like Punjab and Sindh. Likewise, water management projects ranging from the rehabilitation of aging irrigation infrastructures to modern technologies like drip and sprinkler irrigation are crucial for mitigating the sector's growing water stress amid climate variability. In urban environments, investments in green infrastructure, sustainable transport solutions, and nature-based approaches such as urban forests not only improve the quality of life but also enhance resilience to urban heat islands and flooding. On the institutional front, progress in policy integration, inter-agency coordination, capacity building, and the formation of public-private partnerships demonstrates promise in creating a cohesive and sustainable framework for climate action.

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Despite these promising developments, critical gaps persist that may undermine the potential impact of climate-smart initiatives. Persistent institutional fragmentation continues to hinder coordinated response efforts, while limited and inconsistent climate financing particularly for local governments restricts the scalability and long-term sustainability of pilot projects. Data deficiencies and inadequate monitoring systems further compound the challenge by limiting informed decision making at multiple levels of government. Additionally, capacity gaps in technical knowledge and resources across sectors, coupled with insufficient community engagement especially among vulnerable populations such as smallholder farmers and urban poor present ongoing challenges. Finally, the pace of behavioral change among citizens, particularly regarding water conservation and energy use, remains a significant barrier to effective implementation of climate-smart practices. Institutional reforms have emerged as a crucial enabler of effective climate action. Efforts to integrate climate considerations into national development planning, improve inter-agency coordination, and establish public-private partnerships have laid a solid foundation. However, the article finds that institutional fragmentation, limited capacity at local government levels, and insufficient long-term financing are persistent gaps that threaten to undermine these advances. In light of these gaps, achieving sustainable, climate-resilient development in Pakistan will require a concerted effort to enhance inter-agency cooperation, establish robust financing mechanisms, and improve data collection and capacity-building programs. Furthermore, embedding local community insights into the planning and execution of climate interventions will ensure that strategies are context-specific and that adaptation measures are both equitable and inclusive. Bridging these systemic gaps is critical for transforming the current trajectory of climate policy and practice and fully realizing the multifaceted benefits of climate-smart strategies toward achieving a sustainable, inclusive, and resilient future. While Pakistan has made significant progress in deploying climate-smart strategies that span energy, agriculture, water, and urban development, the findings underscore that these initiatives remain at a critical juncture. To build on the gains achieved, there is an urgent need for enhanced financial support, improved data collection, stronger institutional coordination, and more inclusive stakeholder engagement. Addressing these gaps will be essential for transforming current initiatives into a coherent, scalable framework that ensures sustainable development and robust climate resilience for the future.

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