
THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN SUSTAINABLE FOREST MANAGEMENT: A CASE STUDY OF GOVERNMENT AND EDUCATIONAL SECTORS IN PAKISTAN

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Abstract: The escalating threats of deforestation, climate change, and illegal activities necessitate technological innovation in Pakistan's forestry sector. This paper examines the nascent integration of Artificial Intelligence (AI) tools and Machine Learning (ML) techniques within governmental conservation initiatives and academic curricula across the country, driven by the National AI Policy 2025 (Ministry of Information Technology and Telecommunication (MoITT), 2025). Utilizing a qualitative review of policy documents, pilot projects (e.g., the Smart Forest initiative), and educational frameworks, we analyze the current capacity, systemic barriers (including data fragmentation and high infrastructure costs), and future prospects of AI adoption. Findings indicate that government-led adoption, primarily for real-time monitoring and disaster detection, is underway. However, this progress is hampered by significant deficiencies in geospatial data infrastructure, a crucial human capital gap in specialized AI-forestry skills, and a lack of sustainable domestic financing. The paper concludes by proposing a multi-pronged roadmap focusing on data standardization, interdisciplinary education, and innovative finance models to ensure AI becomes a scalable, foundational tool for Pakistan's ecological security and sustainable forest management (SFM).

1. INTRODUCTION

1.1 Background and Context

Forests represent vital natural capital for Pakistan, providing essential ecosystem services such as carbon sequestration, biodiversity conservation, and flood mitigation (Khan et al., 2023). These resources are critically threatened by a rapidly growing population, climate-induced disasters, and illicit activities (Hussain & Ali, 2024). Traditional methods of forest management are often

resource-intensive and lack the required spatial and temporal resolution for effective, proactive conservation.

Globally, the shift toward digital governance has positioned AI as a transformative tool for tackling complex environmental challenges (Ghani et al., 2022). AI offers enhanced capabilities through high-resolution monitoring, predictive modeling of fire risk and pest outbreaks, and real-time alerts for law enforcement against illegal logging. Pakistan formally recognized this potential with the approval of its National AI Policy 2025 (MoITT, 2025), aiming for sectoral transformation, including implicit coverage of resource management and environmental protection.

1.2 General Objective

The general objective of this research is to comprehensively assess the status, scope, and strategic impact of Artificial Intelligence integration within the forestry sector of Pakistan, specifically examining its application in government initiatives and its incorporation into the national educational framework.

1.3 Specific Objectives

The specific objectives of the study are to:

1. identify and analyze the specific AI and Machine Learning applications currently employed by Pakistani government agencies for forest monitoring, protection, and policy planning.
2. evaluate the preparedness and capacity of Pakistan's educational sector to produce the specialized human capital required for scaling AI technologies in environmental and forestry resource management.
3. detail and critically examine the key systemic barriers, including challenges related to data quality, technical infrastructure, and sustainable financing, that impede the full-scale deployment of AI in Pakistani forestry.

1.4 Aim and Scope

The aim of this paper is to provide a grounded analysis and a policy-relevant roadmap for accelerating the sustainable adoption of AI in Pakistan's forestry sector. The scope is delimited to the period 2021–2025, focusing on key national policy documents (e.g., National AI Policy 2025), significant government-led pilot projects, and published literature concerning the technical and educational capacity for AI implementation within the country.

2. REVIEW OF LITERATURE

2.1 AI for Forest Monitoring and Protection

AI, leveraging remote sensing (RS) and deep learning (DL), has become globally dominant in forest surveillance (Javed & Qureshi, 2024). Machine Learning (ML) models are trained on

satellite and drone imagery to classify land cover, detect subtle changes in canopy density indicative of deforestation, and forecast fire hazards with greater speed and accuracy than human-based systems (Ghani et al., 2022). Furthermore, acoustic sensors paired with ML algorithms are now standard for detecting the distinct sounds of chainsaws or vehicles, enabling real-time alerting against illegal activities like poaching and logging (Amin, 2023).

2.2 Policy and Capacity Development in Developing Nations

For developing economies like Pakistan, the primary challenge is often not the availability of the technology itself, but the lack of an enabling environment: data infrastructure, institutional capacity, and a skilled workforce (Oxford Insights, 2024). The launch of national AI policies, such as Pakistan's National AI Policy 2025 (MoITT, 2025), signals high-level government commitment but requires robust downstream implementation to bridge the gap between abstract goals and field operations. Education plays a crucial role, as the effective deployment of AI requires professionals who blend domain expertise (forestry science) with technical skills (data science and ML) (Khan et al., 2023).

3. METHODOLOGY

This research employed a qualitative, descriptive methodology based on a comprehensive review of publicly available institutional and academic documents published between 2021 and 2025.

3.1 Data Sources

The core data comprised:

Government Policy Documents: Including the National AI Policy 2025 (MoITT, 2025) and reports from federal and provincial environmental ministries.

Pilot Project Case Studies: Official reports and press releases detailing major initiatives, notably the "Smart Forest" project by RUDA (Ravi Urban Development Authority, 2021) and international collaborations on fire detection (British High Commission, 2025).

Academic and Grey Literature: Peer-reviewed articles and technical reports focused on geospatial analysis, ML applications in conservation, and digital capacity building within the Pakistani context (e.g., Nawaz & Shah, 2024; Shahid & White, 2024).

3.2 Data Analysis

The collected textual data was subjected to qualitative content analysis. Key themes were systematically identified and categorized across three axes: (1) Specific AI Applications (e.g., acoustic detection, predictive analytics), (2) Capacity Building (e.g., policy goals, curricular mentions), and (3) Systemic Constraints (e.g., data quality, financing). This analysis provided the

basis for the discussion of governmental progress, educational deficiencies, and critical future directions.

4. RESULTS AND DISCUSSION

4.1 AI Use in the Government Forestry Sector: Early Successes

Government adoption of AI in Pakistan is characterized by targeted deployment against the most immediate threats to forest resources, primarily through surveillance and early warning systems.

4.1.1 Smart Forest and Real-Time Surveillance

The launch of the Rakh Jhok Forest ("Smart Forest") near Lahore serves as the most prominent example (RUDA, 2021). This project uses networks of sensors for both resource monitoring (soil, water, tree growth) and security. Most notably, it incorporates acoustic detection ML algorithms trained to differentiate environmental noise from the distinct sound of chainsaws or heavy machinery providing immediate alerts to authorities (Amin, 2023). This capability represents a significant technological leap in combating illegal logging compared to traditional, resource-intensive patrolling.

4.1.2 Disaster Mitigation and Predictive Policy

AI is proving vital for mitigating climate-related risks, particularly forest fires. Initiatives supported by international partners are developing AI systems that use ML to analyze high-resolution satellite imagery for subtle changes in thermal signatures and smoke plumes, providing early detection and tracking, particularly in vulnerable regions like the Margalla Hills (British High Commission, 2025; Javed & Qureshi, 2024). Furthermore, the government is exploring the use of AI/ML for predictive analytics to forecast forest dynamics, such as carbon sequestration potential and species distribution changes under climate change scenarios (Nawaz & Shah, 2024).

4.2 Educational and Human Capital Capacity

While government policy sets an ambitious vision, the educational infrastructure for domain-specific AI skills lags.

4.2.1 National Policy and the General Push

The National AI Policy 2025 prioritizes large-scale human capital development, aiming to train one million AI professionals by 2030 (MoITT, 2025). This general push, supported by initiatives like the Pakistan Engineering Council's (PEC) CPD frameworks, will indirectly benefit forestry by increasing the supply of data scientists.

4.2.2 The Interdisciplinary Gap

The most critical challenge is the curricular gap within established forestry, botany, and environmental science departments. These programs often lack dedicated, mandatory modules in geospatial data analysis, ML for resource management, or AI ethics (Khan et al., 2023). Effective AI deployment demands graduates who are both competent foresters and proficient data scientists, a hybrid skill set that current university structures are not effectively producing.

4.3 Systemic Barriers to Scalability

The path from pilot project success to national scale is blocked by three systemic barriers: Data, Infrastructure, and Finance.

Policy Implication

Data Fragmentation: Essential administrative and environmental data (e.g., land records, historical logging data, ground truth observations) remain siloed, non-standardized, and inaccessible across agencies. This prevents the robust training and validation of national-scale AI models (Ali et al., 2024). Requires immediate implementation of National Spatial Data Infrastructure (NSDI) and mandatory data-sharing protocols.

Infrastructure Costs: Deploying and maintaining extensive IoT sensor networks and high-performance cloud computing required for real-time AI is a high-cost endeavor, and the national digital infrastructure quality remains a concern (Oxford Insights, 2024). Necessitates innovative finance models (e.g., blended finance) and investment in low-cost, decentralized edge-computing solutions.

Sustainable Finance: Pilot projects are often reliant on external donor funding (e.g., GSMA, 2024). A lack of dedicated, sustainable domestic public or private climate financing mechanisms jeopardizes the long-term operational viability of these systems (GIZ, 2024). It requires the creation of targeted climate-smart finance products specifically for technological investments in ecological security (UN in Pakistan, 2025).

5. CONCLUSION

Pakistan is successfully navigating the *adoption* of AI in its forestry sector, primarily through centralized government initiatives focused on immediate threats like fire and illegal logging. However, it faces severe systemic impediments to achieving sustainable and scalable integration. The foundational issues of data fragmentation, the lack of specialized human capital, and inadequate domestic long-term financing must be resolved to fulfill the ambitious goals set by the National AI Policy 2025. To move AI from a collection of isolated pilot projects to a core driver of Sustainable Forest Management (SFM), the following actions are recommended: **Mandate Data Standardization:** Establish a centralized, government-wide data governance framework with legally enforceable protocols for inter-agency sharing of geospatial and administrative data to

create the foundational fuel for national AI models. Integrate Interdisciplinary Curricula: Revise university forestry and environmental science curricula to include mandatory, hands-on training in remote sensing, GIS, and machine learning model deployment, specifically for forest health and resource management. Mobilize Climate-Smart Finance: Develop dedicated financial instruments, potentially leveraging blended finance (public, private, and carbon credit revenue), to guarantee the long-term operational expenditure and scaling of AI infrastructure beyond initial donor funding cycles.

6. REFERENCES

- Ali, A., Ahmad, M., Nawaz, M., & Sattar, F. (2024). The barriers to implementing national spatial data infrastructure in Pakistan: Policy and legislation context. *Journal of Public Policy and Pluralism*, 4(2), 20–35.
- Amin, H. (2023). Acoustic monitoring and machine learning for counter-poaching in South Asia. ResearchGate.
- British High Commission. (2025). *Forest fire prevention technology collaboration with Pakistan: Annual report*. British High Commission.
- Ghani, M. U., Khan, M. A., & Butt, A. A. (2022). Artificial intelligence in environmental governance: Opportunities and challenges for developing nations. *Journal of Environmental Informatics*, 39(2), 114–128.
- GIZ. (2024). *Introduction of innovative climate risk financing solutions in Pakistan: Project report*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).
- GSMA Mobile for Development. (2024). *Combatting forest fires with AI in Pakistan*. GSMA Publications.
- Hussain, S., & Ali, Z. (2024). Climate change and deforestation nexus in Pakistan: Policy implications for sustainable land use. *Pakistan Journal of Environmental Sciences*, 15(1), 45–58.
- Javed, K., & Qureshi, S. (2024). Deep learning for satellite image analysis: Automated Forest fire detection in the Himalayas. *Remote Sensing Applications: Society and Environment*, 35, 100742.
- Khan, R. H., Iqbal, T., & Ahmad, S. (2023). Bridging the gap: Integrating geospatial and data science skills into Pakistani forestry curricula. *Journal of Forestry Research and Development*, 20(4), 312–325.
- Ministry of Information Technology and Telecommunication. (2025). *National Artificial Intelligence Policy 2025: A roadmap for digital Pakistan*. Government of Pakistan.

Nawaz, A., & Shah, M. (2024). Enhancing forest resource management through machine learning-based species distribution modeling in Punjab, Pakistan. *Environmental Monitoring and Assessment*, 196(3), 267.

Oxford Insights. (2024). *Government AI Readiness Index 2024: South and Central Asia rankings*. Oxford Insights.

Ravi Urban Development Authority. (2021). *Project report: Launch of Rakh Jhok 'Smart Forest' initiative*. RUDA Publications.

Shahid, N., & White, L. (2024). *Combatting forest fires with AI in Pakistan*. GSMA Mobile for Development.

United Nations in Pakistan. (2025). *Climate financing and policy recommendations: UN Common Country Analysis (CCA) update 2024*. United Nations.