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LAND RESOURCE GOVERNANCE, LAND USE EFFICIENCY, AND SUSTAINABLE DEVELOPMENT: A COMPARATIVE REVIEW OF CHINA AND PAKISTAN

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ABSTRACT

Land is a vital resource for economic development, food security, and environmental sustainability. Efficient and sustainable use of land requires good governance, proper policies, and careful planning. This review paper examines land resource management, land use efficiency, and land quality transformation in China and Pakistan. It also explores the effects of urban–rural dynamics, ecological security, and sustainable development goals (SDGs) on land use. China's experience with national land space governance, multigoal land policies, and low-carbon city programs provides important lessons for Pakistan, where land management faces institutional and policy challenges. The paper highlights the role of land quality, soil characteristics, and ecological connectivity in improving efficiency and promoting sustainable land use. Furthermore, it discusses how urban expansion, rural land use, and low-carbon transitions influence land markets and ecological outcomes. By comparing the two countries, the review identifies key research gaps, such as the need for more integrated studies on land governance, policy effectiveness, and ecological protection. The findings suggest that combining lessons from China with local practices in Pakistan can help develop more effective land management strategies. This review also points to future research opportunities, including spatial analysis, policy evaluation, and sustainable land use planning.
Keywords: *Land Resource Management; Land Use Efficiency; Land Governance; Sustainable Development; China–Pakistan Comparative Analysis*

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Graphical Abstract

1. INTRODUCTION

Land is a finite and indispensable natural resource that serves as the foundation for human survival, socio-economic development, and environmental sustainability. Effective management of land resources is critical for ensuring food security, promoting economic growth, and maintaining ecological balance, particularly in countries experiencing rapid population growth and urbanization. Both China and Pakistan face pressing land management challenges, including urban sprawl, soil degradation, and uneven land distribution, which have significant implications for national development strategies. While China has adopted rigorous land governance mechanisms, including national land space planning and strict urban–rural land regulation, Pakistan is still developing its institutional capacity for comprehensive land resource management (Mangi et al., 2020). The management of land resources requires integrating economic, environmental, and social dimensions, necessitating multidisciplinary approaches that combine geography, economics, policy studies, and environmental sciences. Globally, increasing research attention is being directed toward understanding how land use planning, governance, and policy interventions can optimize land utilization while minimizing ecological degradation (Pandey et al., 2021). In the context of sustainable development, this holistic perspective is crucial for balancing economic growth with environmental protection. Despite significant advances, gaps remain in understanding the comparative effectiveness of land management strategies in different socio-economic and institutional contexts, particularly between developing and emerging economies. A systematic review focusing on China and Pakistan offers a valuable opportunity to synthesize lessons from different policy environments, institutional arrangements, and land use practices, thereby providing insights for designing more effective land governance frameworks (Zhang et al., 2025). Furthermore, integrating land efficiency and quality measures into the analysis enhances our understanding of how resources can be optimally allocated while sustaining long-term productivity. This review aims to provide a comprehensive synthesis of land resource management concepts, practices, and challenges with a focus on the comparative perspectives of China and Pakistan (Taheri et al., 2024).

Land plays a pivotal role in shaping the economic and social development trajectory of nations, serving as a primary input for agriculture, industry, and infrastructure development (Bockstael, 1996;

World Bank, 2020). Productive land supports agricultural output, ensures food security, and drives rural livelihoods, while urban land facilitates industrialization, housing, and transportation networks essential for economic growth (Liu et al., 2018). In rapidly developing countries like China, efficient land allocation has enabled sustained urban expansion and industrial growth, contributing to the country's position as a global economic powerhouse (Zhang et al., 2017). Similarly, Pakistan's economic growth is closely linked to land resources, particularly in agriculture-dominated regions, where land quality and access determine productivity and social welfare outcomes (Ali & Chaudhry, 2018). Beyond its economic value, land also possesses cultural, historical, and ecological significance, underscoring the need for sustainable management practices that consider both human and environmental needs (FAO, 2017). Land mismanagement can lead to inefficient resource allocation, socio-economic disparities, environmental degradation, and increased vulnerability to natural disasters (Liu et al., 2018; World Bank, 2020). Consequently, the integration of land economics, policy evaluation, and governance frameworks becomes critical for optimizing land use, ensuring equitable distribution, and achieving sustainable development objectives (Borras & Franco, 2012). Analyzing the role of land in both economic and social dimensions provides a foundation for understanding the complex trade-offs between urbanization, industrialization, agricultural productivity, and environmental conservation (Liu et al., 2018; Zhang et al., 2017). This review emphasizes the need to examine how policy interventions, efficiency measures, and governance mechanisms influence land allocation and utilization patterns, particularly in contexts where resource scarcity and population pressures are significant (Borras & Franco, 2012; Ali & Chaudhry, 2018). By focusing on China and Pakistan, the review identifies strategies that enhance land productivity while supporting inclusive development and social equity (Zhang et al., 2017; FAO, 2017).

Rapid urbanization poses significant challenges to land resource management, particularly in balancing urban expansion with the preservation of rural land and ecological integrity (Liu et al., 2018; Zhang et al., 2017). In China, the urban population has grown exponentially over the past few decades, leading to extensive conversion of arable and ecological land into construction and industrial zones (Li et al., 2020). Policies such as the National Land Space Planning and multigoal land use policy aim to mitigate these effects by regulating urban sprawl and improving land use efficiency (Zhang et al., 2017). In Pakistan, urbanization is also accelerating, but governance frameworks are less centralized and often fragmented, resulting in unplanned urban growth, encroachment on agricultural lands, and environmental degradation (Ali & Chaudhry, 2018). Rural areas face additional challenges, including land fragmentation, declining soil fertility, and inefficient agricultural practices, which threaten long-term food security and rural livelihoods (FAO, 2017). The interaction between urban and rural land systems is complex, as urban expansion often competes with agricultural and ecological land uses, creating trade-offs between development objectives and environmental sustainability (Borras & Franco, 2012). Effective urban–rural land integration requires understanding spatial patterns, land use efficiency, and governance mechanisms that can harmonize competing interests (Liu et al., 2018). Comparative studies between China and Pakistan provide valuable insights into how different policy regimes, planning strategies, and institutional capacities influence the outcomes of urbanization on rural land resources (Zhang et al., 2017). This review highlights the importance of examining both urban and rural contexts to identify strategies that enhance land use efficiency, promote sustainable development, and maintain ecological balance (FAO, 2017).

The sustainable management of land resources is inseparable from ecological and environmental considerations, as land use directly impacts biodiversity, soil health, water availability, and climate regulation (Li et al., 2020; Liu et al., 2018). Unsustainable land exploitation, such as deforestation, overgrazing, and intensive cultivation, can lead to severe environmental degradation, including soil erosion, loss of fertility, desertification, and reduced carbon sequestration capacity (FAO, 2017). In China, ecological protection policies and urban-rural ecological network planning have been implemented to address environmental challenges while supporting development, including the designation of ecological corridors and protected zones (Zhang et al., 2017). Pakistan faces similar environmental concerns, particularly in arid and semi-arid regions where soil degradation and water scarcity exacerbate vulnerability to climate change (Ali & Chaudhry, 2018). Integrating ecological principles into land governance and spatial planning ensures that development does not compromise environmental sustainability (Liu et al., 2018). Tools such as ecological security patterns, landscape connectivity analysis, and multi-species corridor modeling provide frameworks for maintaining ecological integrity while optimizing land use (Li et al., 2020). This review emphasizes the need to incorporate environmental considerations alongside economic and social factors in land management strategies (FAO, 2017). Comparative analyses of China and Pakistan reveal opportunities for adopting best practices in ecological conservation, including the use of decision support systems, GIS technologies, and policy instruments that balance human needs with ecosystem preservation (Zhang et al., 2017).

While land quantity has traditionally been the focus of land management studies, land quality and efficiency are increasingly recognized as critical determinants of sustainable land use (Bockstael, 1996; Li et al., 2020). Land use efficiency refers to the optimal allocation of land resources to maximize economic output, social welfare, and ecological benefits, while land quality encompasses soil fertility, slope, water retention, and other biophysical characteristics influencing productivity (Liu et al., 2018). Research in China has demonstrated that integrating land quality indicators, such as soil organic carbon, into efficiency analyses improves the accuracy and realism of land use assessments (Li et al., 2020). In Pakistan, however, studies often emphasize quantity-based measures, with limited attention to soil quality, land degradation, and technical efficiency (Ali & Chaudhry, 2018). Incorporating land quality into land resource management enables policymakers to identify high-value agricultural zones, optimize urban expansion, and design targeted interventions to prevent degradation (FAO, 2017). Additionally, understanding efficiency heterogeneity across regions and land types informs the design of region-specific policies that improve productivity while maintaining environmental sustainability (Bockstael, 1996). This review underscores the importance of synthesizing evidence on both land quantity and quality, highlighting lessons from China that could inform sustainable land use practices in Pakistan and beyond (Zhang et al., 2017).

Land use decisions are intrinsically linked to the achievement of Sustainable Development Goals (SDGs), including zero hunger (SDG 2), sustainable cities (SDG 11), climate action (SDG 13), and life on land (SDG 15) (United Nations, 2015). Trade-offs often arise between economic development, urbanization, and ecological protection, requiring integrated strategies that optimize land use without compromising sustainability objectives (Liu et al., 2018). Studies in China indicate that achieving SDGs influences both the quantity and quality of land use, with governance and institutional frameworks playing a crucial role in mediating these effects (Zhang et al., 2017). Pakistan's progress toward SDG implementation is constrained by institutional fragmentation, lack of spatial planning, and limited monitoring of land resources (Ali & Chaudhry, 2018). This review highlights how comparative analysis can identify synergies and trade-offs between development objectives and land use patterns, informing policy interventions that promote equitable, efficient, and sustainable resource allocation (Borras & Franco, 2012). Incorporating SDG frameworks into land management research strengthens the link between policy evaluation, governance, and long-term sustainability outcomes (United Nations, 2015).

Effective land governance encompasses legal, institutional, and policy mechanisms that regulate land use, ensure equitable allocation, and prevent resource degradation (Borras & Franco, 2012; World Bank, 2020). In China, national land space governance frameworks integrate centralized planning, zoning regulations, and performance-based monitoring to optimize land allocation and protect ecological resources (Zhang et al., 2017). Pakistan, in contrast, faces challenges related to fragmented land tenure systems, inconsistent policy enforcement, and limited technical capacity for spatial planning (Ali & Chaudhry, 2018). Comparative studies reveal that governance structures significantly influence land use efficiency, sustainability outcomes, and socio-economic equity (Bockstael, 1996; Liu et al., 2018). Policies such as urban-rural integration, land consolidation, and environmental regulation directly affect land markets, agricultural productivity, and ecological integrity (Li et al., 2020). This review emphasizes the need to understand governance mechanisms and institutional contexts, as these determine the effectiveness of policy instruments, the adoption of sustainable practices, and the achievement of national development goals (World Bank, 2020).

Land use decisions have substantial implications for climate change mitigation and adaptation, as land is both a source and sink of greenhouse gas emissions (FAO, 2017; Li et al., 2020). Low-carbon urban development, sustainable agriculture, and ecological restoration are essential strategies for reducing emissions associated with land use (Zhang et al., 2017). China has implemented low-carbon city pilots and industrial land regulation policies to address environmental concerns, while Pakistan's efforts are emerging but face implementation and resource challenges (Ali & Chaudhry, 2018). Land-driven carbon management requires integrating efficiency measures, ecological considerations, and governance frameworks to ensure that land allocation supports environmental sustainability (Li et al., 2020). This review examines how land policies in both countries influence carbon outcomes, identifies research gaps in low-carbon land strategies, and highlights opportunities for integrating environmental objectives into national and regional land management practices (FAO, 2017).

Despite substantial research on land management, governance, and efficiency, several gaps remain, particularly in comparative studies between China and Pakistan (Bockstael, 1996; Liu et al., 2018). Existing literature often focuses on either urban or rural land, emphasizes quantity over quality, or neglects ecological and climate considerations (Zhang et al., 2017). Furthermore, the effectiveness of policy interventions, integration of SDGs, and assessment of governance mechanisms remain underexplored in a comparative context (Borras & Franco, 2012). This review aims to synthesize evidence on land resource management, land use efficiency, governance, ecological security, and sustainable development in China and Pakistan (FAO, 2017; World Bank, 2020). By highlighting similarities, differences, and best practices, the review identifies critical research gaps and proposes directions for future empirical studies that combine technical efficiency, land quality, policy evaluation, and sustainability objectives (Li et al., 2020). The findings will provide insights for policymakers, planners, and researchers seeking to optimize land resource utilization while supporting long-term socio-economic and environmental outcomes (United Nations, 2015).

2. Land Resource Management: Concepts and Theories

Land resources refer to the naturally occurring terrestrial areas that provide essential services for human survival, economic development, and ecological sustainability (FAO, 2017; Liu et al., 2018). They include arable land, forests, grasslands, wetlands, deserts, and urbanized areas (Bockstael, 1996). The categorization of land is crucial for efficient allocation and sustainable utilization (Li et al., 2020). Arable land is primarily used for agriculture, forests for timber and biodiversity conservation, and grasslands for livestock grazing (FAO, 2017). Wetlands support water filtration and flood control, while urban areas cater to housing, commerce, and industry (Liu et al., 2018). In China, land resources are tightly regulated under the national land use planning framework, with strict zoning for agricultural and construction purposes (Zhang et al., 2017). Pakistan, on the other hand, faces challenges in land classification due to fragmented governance and less systematic mapping (Ali & Chaudhry, 2018). Understanding the types of land resources is the foundation of land resource management and enables policymakers to design strategies that optimize use while protecting ecological functions (Borras & Franco, 2012).

2.1. Land Management Frameworks

Land management frameworks provide structured approaches to govern the allocation, utilization, and conservation of land (Borras & Franco, 2012; World Bank, 2020). They encompass legal, institutional, and policy mechanisms designed to balance economic development with environmental sustainability (Liu et al., 2018). In China, the *National Land Use Master Plan* integrates spatial planning, ecological protection, and economic objectives (Zhang et al., 2017; Li et al., 2020). Similarly, Pakistan has introduced provincial-level land use policies, though enforcement remains inconsistent (Ali & Chaudhry, 2018). Frameworks often rely on zoning, land-use permits, and environmental impact assessments to ensure sustainable utilization (FAO, 2017). Additionally, frameworks incorporate monitoring systems, data collection, and stakeholder participation (World Bank, 2020). Internationally, best practices advocate for adaptive frameworks that respond to urbanization pressures, climate change, and population growth (Bockstael, 1996; Li et al., 2020). These frameworks serve as a guide for both strategic planning and operational decisions in land management (Liu et al., 2018).

Table 2. Comparison of Land Governance Frameworks in China and Pakistan

Dimension	China	Pakistan
Governance Structure	Centralized	Decentralized
Land Ownership	State & collective	Private, state, communal
Planning System	National Land Space Planning	Provincial planning
Monitoring Tools	GIS, RS, DSS	Limited GIS, surveys
Enforcement	Strong	Weak to moderate

2.2. Land Economics and Policy Evaluation

Land economics studies the optimal allocation of land to maximize societal benefits, considering scarcity, opportunity costs, and externalities (Bockstael, 1996; Liu et al., 2018). It involves analyzing supply-demand dynamics, land pricing, and the impact of regulatory measures on land use patterns (Li et al., 2020). Policy evaluation within land economics assesses the effectiveness of land-use regulations, zoning laws, and market interventions (Zhang et al., 2017; World Bank, 2020). For instance, China's land quota system controls farmland conversion, while Pakistan's land tenure reforms aim to enhance equitable access (Ali & Chaudhry, 2018). Evaluating such policies involves measuring economic efficiency, equity, and sustainability outcomes (Borras & Franco, 2012). Comparative studies reveal that efficient land markets reduce conflicts, prevent overexploitation, and encourage investment in land productivity, but these outcomes are heavily dependent on institutional robustness and governance quality (FAO, 2017; Liu et al., 2018).

2.3. Resource Allocation Efficiency

Resource allocation efficiency in land management assesses how effectively land resources are utilized to meet multiple objectives, such as food production, housing, and ecological protection (Bockstael, 1996; Liu et al., 2018). Technical efficiency focuses on maximizing output from a given input, while allocative efficiency considers optimal resource distribution across competing uses (Li et al., 2020). China's large-scale land consolidation programs have improved allocative efficiency by reducing fragmented holdings and encouraging mechanized agriculture (Zhang et al., 2017). In Pakistan, inefficiencies persist due to fragmented land holdings, informal tenure systems, and limited adoption of modern agricultural techniques (Ali & Chaudhry, 2018). Measuring efficiency often involves Data Envelopment Analysis (DEA) and frontier production functions, enabling policymakers to identify gaps between actual and optimal land use (FAO, 2017). Efficient allocation reduces wastage, enhances productivity, and contributes to sustainable land governance (Borras & Franco, 2012; World Bank, 2020).

2.4. Land Tenure and Property Rights

Secure land tenure and clearly defined property rights are fundamental for sustainable land management (Borras & Franco, 2012; World Bank, 2020). They incentivize owners to invest in soil improvement, irrigation, and long-term land stewardship (Bockstael, 1996; FAO, 2017). China's collective land ownership system balances individual use rights with centralized control, while Pakistan has a mix of private, communal, and state-owned land, leading to disputes and underutilization (Ali & Chaudhry, 2018; Zhang et al., 2017). Weak property rights often result in land degradation, speculative transactions, and limited access to credit for agricultural investments (Li et al., 2020). Strengthening tenure security and formalizing property records are essential policy measures to promote efficient and sustainable land use (Liu et al., 2018). Comparative analysis between the two countries highlights the importance of robust legal frameworks and enforcement mechanisms in achieving equitable land management outcomes (Borras & Franco, 2012; World Bank, 2020).

Table 1. Classification of Land Resources and Their Functions

Land Type	Key Characteristics	Main Economic Functions	Ecological Functions	Examples (China / Pakistan)
Arable Land	Fertile soils, irrigation	Crop production, food security	Carbon storage, soil health	North China Plain / Punjab plains
Forest Land	High biomass, biodiversity	Timber, eco-tourism	Carbon sequestration, biodiversity	Sichuan forests / KP forests
Grassland	Natural vegetation	Livestock grazing	Soil conservation, carbon sink	Inner Mongolia / Balochistan
Wetlands	Water-saturated soils	Fisheries, flood control	Water purification, biodiversity	Yangtze wetlands / Indus delta
Urban Land	Built-up areas	Housing, industry, transport	Limited ecological role	Beijing / Lahore

2.5. Market vs. Government Roles in Land Use

Land use outcomes are shaped by the interplay between market forces and government interventions (Bockstael, 1996; Liu et al., 2018). Markets can efficiently allocate land to its highest-valued use, but may neglect ecological and social considerations (Li et al., 2020). Governments intervene through zoning regulations, conservation policies, and fiscal incentives to correct market failures (FAO, 2017; World Bank, 2020). In China, state-led land policies, such as urban-rural planning integration and farmland protection, have guided sustainable development (Zhang et al., 2017). Pakistan's land markets are less regulated, often leading to unplanned urban expansion and overexploitation of natural resources (Ali & Chaudhry, 2018). Effective land resource management requires a balanced approach where market mechanisms operate within a strong regulatory framework that prioritizes sustainability and public welfare (Borras & Franco, 2012).

2.6. Integrated Land Use Planning Approaches

Integrated land use planning combines ecological, economic, and social dimensions to guide sustainable land development (Liu et al., 2018; Li et al., 2020). It involves multi-sectoral coordination, spatial analysis, and participatory decision-making (FAO, 2017). China's National Land Space Governance framework exemplifies an integrated approach, linking urban expansion, agriculture, and environmental protection (Zhang et al., 2017). Pakistan is gradually adopting similar approaches in urban master planning and floodplain management, but lacks nationwide integration (Ali & Chaudhry, 2018). Tools such as Geographic Information Systems (GIS), remote sensing, and scenario modeling help visualize land use patterns, assess trade-offs, and plan future interventions (Bockstael, 1996; Li et al., 2020). Integrated planning enhances resilience, reduces conflicts, and promotes balanced land utilization across competing sectors (World Bank, 2020).

Figure 1: Conceptual Framework of Integrated Land Resource Management

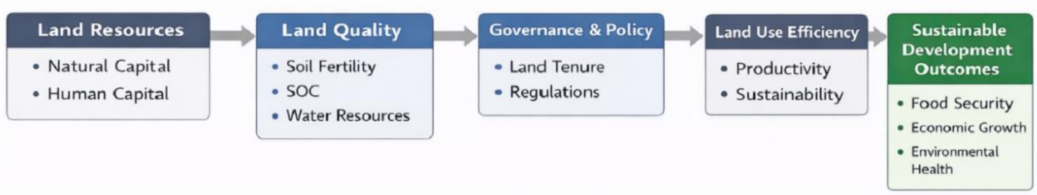

Figure 1: Conceptual Framework of Integrated Land Resource Management

The overall conceptual framework guiding this review is presented in Figure 1, illustrating the integrated relationships among land resources, land quality, governance mechanisms, and sustainable development outcomes.

2.7. Decision Support Systems in Land Management

Decision support systems (DSS) utilize data, models, and analytical tools to aid land management decisions (Bockstael, 1996; Liu et al., 2018). They incorporate spatial data, land use simulations, environmental impact assessments, and policy evaluation modules (Li et al., 2020; FAO, 2017). China has deployed DSS to monitor farmland conversion, optimize urban-rural land allocation, and support ecological zoning (Zhang et al., 2017). In Pakistan, DSS applications are emerging in urban planning and disaster risk management but are limited by data quality and technical capacity (Ali & Chaudhry, 2018). DSS improves transparency, objectivity, and efficiency in land governance (World Bank, 2020). By simulating different scenarios, policymakers can assess trade-offs between economic, ecological, and social objectives, making it a critical tool for evidence-based land management (Li et al., 2020).

3. Land Use Efficiency: Concepts and Measurement

3.1. Definition of Land Use Efficiency (LUE)

Land Use Efficiency (LUE) is a measure of how effectively land resources are utilized to generate economic, social, and ecological benefits (Bockstael, 1996; Liu et al., 2018). It evaluates the relationship between land inputs, such as area, labor, capital, and technology, and the outputs derived, including agricultural production, urban development, and ecosystem services (Li et al., 2020). LUE is increasingly recognized as a multidimensional concept encompassing both technical efficiency (maximizing outputs from given inputs) and allocative efficiency (optimal distribution of land among competing uses) (FAO, 2017). High LUE ensures sustainable land utilization by balancing productivity with conservation (Zhang et al., 2017). In China, LUE is monitored using national land-use datasets and spatial planning tools, reflecting government policies to optimize farmland use, control urban sprawl, and protect ecologically sensitive areas (Li et al., 2020; Liu et al., 2018). In Pakistan, LUE assessment is less systematic due to fragmented land records and informal land-use practices, but pilot studies in Punjab and Sindh provinces indicate significant efficiency gaps in agricultural land management (Ali & Chaudhry, 2018). Defining and measuring LUE provides a foundational framework for understanding land management performance, comparing regions, and identifying areas for policy intervention (Borras & Franco, 2012; World Bank, 2020).

3.2. Technical vs. Allocative Efficiency

Technical efficiency refers to the ability of land to produce the maximum possible output with a given set of inputs, without considering market prices or resource allocation (Bockstael, 1996; Liu et al., 2018). Allocative efficiency, in contrast, evaluates whether land is being used in the most economically optimal way, considering the relative value of outputs and inputs (Li et al., 2020; FAO, 2017). Both are critical for sustainable land management (Borras & Franco, 2012). In China, urban-rural land consolidation policies aim to enhance technical efficiency by integrating fragmented agricultural plots, improving mechanization, and applying precision farming techniques (Zhang et al., 2017; Li et al., 2020). Allocative efficiency is addressed through strict zoning regulations and market-oriented land transfers that encourage land to flow toward higher-value uses (Liu et al., 2018). In Pakistan, technical efficiency is often constrained by traditional farming practices, irregular irrigation, and limited mechanization, while allocative inefficiencies arise due to weak land markets and tenure insecurity (Ali & Chaudhry, 2018). Comparative analysis highlights that improving technical efficiency without addressing allocative mechanisms may not lead to sustainable outcomes, emphasizing the need for integrated efficiency measurement (World Bank, 2020).

3.3. Role of Land Quality in Efficiency

Land quality is a crucial determinant of Land Use Efficiency (LUE), as variations in soil fertility, slope, water availability, and ecological integrity directly affect land productivity (Bockstael, 1996; Liu et al., 2018). Traditional efficiency measurements focus on land area alone, neglecting differences in land quality (Li et al., 2020). Dr. Jin Gui's research emphasizes incorporating soil organic carbon (SOC), land slope, and other ecological indicators into efficiency models to reflect true productivity (Zhang et al., 2017). In China, research has shown that high-quality arable land significantly outperforms marginal land, and policies prioritize its protection under the farmland redline system (Li et al., 2020; Liu et al., 2018). In Pakistan, the lack of systematic soil quality assessment and data-driven land classification limits efficiency optimization, particularly in hilly or marginal regions (Ali & Chaudhry, 2018). Incorporating land quality into LUE models allows policymakers to target interventions, improve resource allocation, and design compensation mechanisms for preserving ecologically sensitive land (FAO, 2017; World Bank, 2020).

3.4. Efficiency Indicators and Metrics

Measuring Land Use Efficiency (LUE) requires standardized indicators and metrics that capture both input utilization and output performance (Bockstael, 1996; Liu et al., 2018). Common metrics include land output per unit area, crop yield efficiency, production frontier efficiency scores, and land use intensity indices (Li et al., 2020; FAO, 2017). Advanced approaches integrate ecological and social outcomes, such as biodiversity preservation and food security contributions (Zhang et al., 2017). China has developed a series of land-use efficiency monitoring frameworks at national and provincial levels, combining statistical, remote sensing, and geospatial data (Li et al., 2020; Liu et al., 2018). Pakistan, while lacking comprehensive frameworks, has employed metrics like land productivity indices and irrigation efficiency to evaluate agricultural land (Ali & Chaudhry, 2018). Multi-dimensional indicators provide a holistic view of land performance, enabling policymakers to balance economic growth, social equity, and ecological protection, which is particularly relevant for comparative studies across regions with diverse land characteristics (Borras & Franco, 2012; World Bank, 2020).

3.5. Data Envelopment Analysis (DEA) and Frontier Models

Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are widely applied to quantify technical and allocative efficiency of land (Bockstael, 1996; Liu et al., 2018). DEA is a non-parametric method that evaluates relative efficiency among decision-making units by comparing observed outputs with an efficient frontier, while SFA estimates efficiency while accounting for statistical noise (Li et al., 2020; FAO, 2017). These models allow for multi-input and multi-output scenarios, including land area, labor, capital, soil quality, and ecological outputs (Zhang et al., 2017). Chinese studies frequently use DEA to analyze urban-rural differences and policy impacts on land efficiency, whereas in Pakistan, frontier models have been applied to agricultural performance in Punjab and Sindh (Ali & Chaudhry, 2018). Incorporating land quality indicators like soil organic carbon (SOC) and slope into frontier models improves accuracy and policy relevance (Li et al., 2020). Frontier analysis identifies efficiency gaps, best-practice benchmarks, and potential improvements in resource allocation, making it an essential tool for evidence-based land management (Borras & Franco, 2012; World Bank, 2020).

Table 4. Comparison of Technical and Allocative Efficiency in China and Pakistan

Efficiency Type	China	Pakistan
Technical Efficiency	High due to mechanization	Low to moderate
Allocative Efficiency	Strong zoning & markets	Weak land markets
Major Constraints	Urban pressure	Fragmented tenure
Policy Tools	Land consolidation, zoning	Land reforms, irrigation

3.6. Spatial Analysis of Efficiency

Land efficiency is highly spatially heterogeneous due to variations in topography, land quality, infrastructure, and socio-economic conditions (Bockstael, 1996; Liu et al., 2018). GIS and remote sensing tools are increasingly used to visualize efficiency patterns, detect hotspots of underutilization, and plan interventions (Li et al., 2020; FAO, 2017). In China, spatially explicit efficiency analysis has revealed that rural areas often lag behind urban regions in technical and allocative efficiency, highlighting regional disparities (Zhang et al., 2017; Li et al., 2020). In Pakistan, spatial analysis identifies inefficiencies in flood-prone plains and marginal uplands, showing the need for location-specific policies (Ali & Chaudhry, 2018). Mapping efficiency supports decision-making at multiple scales, from local land use planning to national policy formulation, and helps integrate ecological, economic, and social dimensions into land management strategies (Borras & Franco, 2012; World Bank, 2020).

3.7. Efficiency Differences Across Urban and Rural Areas

Urban and rural lands exhibit distinct efficiency characteristics (Bockstael, 1996; Liu et al., 2018). Urban areas are generally capital- and technology-intensive, yielding high economic output per unit land, but may experience ecological stress due to density and pollution (Li et al., 2020; FAO, 2017). Rural lands are often labor-intensive and resource-dependent, with efficiency affected by soil quality, irrigation, and access to markets (Ali & Chaudhry, 2018). In China, urban-rural integration policies aim to redistribute resources and improve rural efficiency through mechanization, infrastructure development, and technology transfer (Zhang et al., 2017; Li et al., 2020). Pakistan faces larger disparities, with rural areas constrained by fragmented landholding and limited access to inputs (Ali & Chaudhry, 2018). Understanding urban-rural efficiency differences informs targeted policies, supports balanced development, and enhances overall land resource utilization (Borras & Franco, 2012; World Bank, 2020).

3.8. Comparative Approaches (China vs. Pakistan)

Comparative studies of Land Use Efficiency (LUE) between China and Pakistan reveal lessons for policy and governance (Bockstael, 1996; Liu et al., 2018). China's strong regulatory framework, advanced monitoring systems, and integration of land quality into planning contribute to relatively higher efficiency (Li et al., 2020; Zhang et al., 2017). Pakistan, with weaker governance, less reliable data, and fragmented land tenure, experiences larger efficiency gaps (Ali & Chaudhry, 2018). Comparative analysis highlights the importance of combining technical, allocative, and quality-based efficiency measures, and the need for context-specific policy interventions (Borras & Franco, 2012; FAO, 2017). Lessons from China's successful consolidation programs, farmland protection policies, and efficiency monitoring frameworks can inform reforms in Pakistan, particularly in agriculture, urban planning, and ecological land management (Li et al., 2020; World Bank, 2020).

Table 3. Indicators of Land Use Efficiency (LUE)

Indicator Category	Indicators	Description
Input Indicators	Land area, labor, capital	Resources used in production
Output Indicators	Crop yield, GDP, ecosystem services	Economic & ecological outcomes
Quality Indicators	SOC, soil fertility, slope	Productivity constraints
Ecological Indicators	Carbon stock, biodiversity	Environmental sustainability
Social Indicators	Employment, food security	Welfare impact

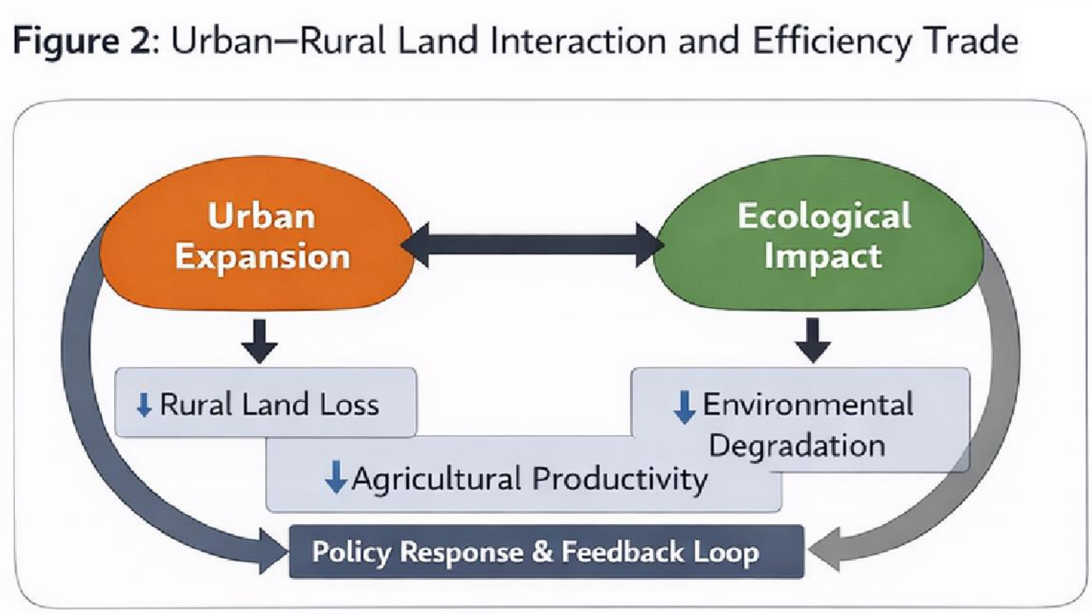

Figure 2: Analytical Framework of Land Use Efficiency (LUE) Measurement

The analytical framework used for evaluating land use efficiency, integrating DEA, SFA, and land quality indicators, is illustrated in Figure 2.

4. Land Quality Assessment and Sustainable Agriculture

4.1. Importance of Land Quality in Agriculture

Land quality is a critical determinant of agricultural productivity, sustainability, and environmental protection (Bockstael, 1996; Liu et al., 2018). It encompasses physical, chemical, and biological properties, including soil fertility, texture, organic matter, water retention, and slope stability (Li et al., 2020; FAO, 2017). High-quality land supports greater crop yields, reduces the need for chemical inputs, and maintains ecological balance (Zhang et al., 2017). In China, farmland protection policies prioritize high-quality land for staple crops, with soil conservation and organic amendments enhancing long-term productivity (Li et al., 2020; Liu et al., 2018). Pakistan faces challenges due to soil degradation, salinization, and erosion, particularly in irrigated plains and hilly areas (Ali & Chaudhry, 2018). Sustainable agriculture relies on understanding and managing land quality to ensure food security, mitigate land degradation, and support rural livelihoods (Borras & Franco, 2012; World Bank, 2020).

4.2. Indicators of Land Quality

Land quality assessment uses indicators such as soil organic carbon (SOC), nutrient content, pH, slope, water availability, and biodiversity (Bockstael, 1996; Liu et al., 2018). SOC is a key indicator of soil fertility, influencing crop growth and ecological health (Li et al., 2020; FAO, 2017). Soil texture affects water retention and root development, while slope and erosion risk determine land usability (Zhang et al., 2017). China has integrated these indicators into national land evaluation frameworks, linking soil quality data with land-use planning (Li et al., 2020; Liu et al., 2018). In Pakistan, studies have focused on crop yield, irrigation efficiency, and soil fertility mapping, but comprehensive soil quality databases are limited (Ali & Chaudhry, 2018). Accurate land quality indicators allow policymakers and farmers to make informed decisions, optimize land use, and prioritize conservation interventions (Borras & Franco, 2012; World Bank, 2020).

4.3. Land Degradation and Erosion Issues

Land degradation, including erosion, salinization, desertification, and nutrient depletion, is a major constraint on sustainable agriculture (Lal, 2015; Oldeman et al., 2020). In China, steeply sloped lands are at risk of erosion but are sometimes cultivated due to population pressure, while programs like the Grain for Green initiative convert marginal lands into forests to reduce erosion and restore ecological balance (Chen et al., 2017; Liu & Zhang, 2019). Pakistan experiences severe soil erosion in upland areas and salinization in irrigated plains, reducing productivity and income (Khan et al., 2018). Monitoring degradation through remote sensing and field assessments enables early intervention and informed decision-making (Huang et al., 2020). Sustainable agriculture strategies must integrate erosion control, soil restoration, and reforestation to maintain land productivity and ecological balance (Singh et al., 2016; Wang et al., 2018).

4.4. Crop Productivity and Land Quality Linkages

High land quality is strongly correlated with higher crop productivity and improved resource efficiency (Montgomery, 2007; Pretty et al., 2018). In China, empirical studies integrating soil organic carbon (SOC) and soil fertility indicators into agricultural production models have demonstrated that higher-quality farmland significantly increases output per unit area, thereby enhancing both technical and allocative efficiency (Li et al., 2019; Deng et al., 2021). In Pakistan, agricultural productivity is constrained by poor soil conditions, salinity, and nutrient depletion, which necessitate higher fertilizer use and intensive irrigation, increasing production costs and environmental stress (Khan et al., 2012; Mahmood et al., 2017). Understanding these interlinkages enables targeted interventions such as precision nutrient management, conservation tillage, and crop rotation systems, which can enhance sustainable productivity while minimizing ecological degradation (Rockström et al., 2017; Zhang et al., 2020).

4.5. Sustainable Agricultural Practices

Sustainable agriculture seeks to maximize productivity while conserving land resources, water, and biodiversity through practices such as crop rotation, organic farming, integrated pest management, conservation tillage, and agroforestry (Tilman et al., 2011; Pretty & Bharucha, 2014). In China, integrated soil–crop management systems and ecological agriculture practices have significantly improved crop yields and environmental sustainability, particularly in marginal and degraded lands (Chen et al., 2014; Zhang et al., 2019). In Pakistan, conservation agriculture and water-efficient irrigation techniques are increasingly promoted; however, adoption remains limited due to insufficient awareness, institutional support, and technical capacity among farmers (Hussain et al., 2015; Qureshi et al., 2018). These sustainable practices not only enhance soil quality and land productivity but also increase resilience against climate variability and economic shocks, thereby supporting long-term agricultural sustainability (Altieri et al., 2015; Rockström et al., 2017).

4.6. Policy Approaches to Land Quality Improvement

Governments play a crucial role in protecting and improving land quality through policies, programs, and institutional frameworks that support soil conservation, ecological restoration, and sustainable land use (OECD, 2024; FAO, 2021). In China, farmland protection regulations — including the permanent basic farmland system and ecological compensation mechanisms — are integral to national land planning and aim to maintain both the quantity and quality of agricultural land while preventing soil degradation (Wang et al., 2023; Grain for Green, 2025). Pakistan has implemented various land improvement efforts through reclamation projects, fertilizer distribution programs, and irrigation infrastructure enhancements, though inconsistent enforcement and weak monitoring often limit their effectiveness (UNCTAD, 2023). Effective policy requires integrating scientific land quality assessment with economic incentives and capacity-building initiatives for farmers, alongside systematic monitoring frameworks to track and evaluate outcomes (OECD, 2024; LIMS Pakistan, 2025). Comparative studies show that structured policies supported by **community engagement and participatory approaches** are more successful in improving land quality and agricultural outcomes than top-down interventions alone (FFTC-AP, 2024; PAI Pakistan, 2020).

4.7. Role of Technology and Decision Support Systems

Technological tools, including Geographic Information Systems (GIS), remote sensing, and Decision Support Systems (DSS), are essential for land quality assessment and sustainable land management because they enable spatial monitoring, change detection, and modeling of land cover dynamics (Batool et al., 2023; Rehman et al., 2022). In China, satellite imagery and soil datasets are extensively used with spatial analysis techniques to monitor land degradation, land use/land cover changes, and vegetation indices that guide policy interventions and ecological restoration (Dainelli & Saracco, 2023). Pakistan is gradually incorporating GIS and DSS for irrigation management, soil mapping, and landscape suitability assessment, improving decision-making in agricultural planning (Hassan et al., 2016; Batool et al., 2023). These technologies allow precise identification of degraded or high-quality land and support spatial planning for optimized sustainable agricultural practices (Rehman et al., 2022). Integration of technological tools with policy frameworks improves the effectiveness and ecological soundness of land management interventions (Dainelli & Saracco, 2023).

4.8. Comparative Experiences from China and Pakistan

China's structured land quality evaluation and farmland protection initiatives have been linked to measurable improvements in agricultural productivity, soil health, and ecological sustainability. Large-scale ecological restoration programmes such as the *Grain for Green* (or Sloping Land Conversion Programme) have significantly increased vegetation cover, reduced soil erosion, and enhanced soil organic carbon stocks on degraded landscapes such as the Loess Plateau, where converting cropland to forest and grassland catalysed improvements in ecosystem services (Zhang et al., 2014; Sun et al., 2020). National soil quality monitoring systems and farmland quality surveys are further being expanded to systematically evaluate arable land conditions and inform adaptive management strategies (Guo, 2023). In contrast, Pakistan — despite its substantial agricultural potential — faces persistent challenges from land degradation linked to soil erosion, salinization, fragmented governance, and limited nationwide monitoring frameworks, resulting in lower land use efficiency and agricultural productivity (Gilani et al., 2021; FAO, 2025). Comparative insights suggest that Pakistan can benefit from adopting integrated land quality assessment frameworks, stronger regulatory mechanisms, and incentives for sustainable practices, while China's experience in policy design and large-scale implementation offers lessons for enhancing national land management strategies.

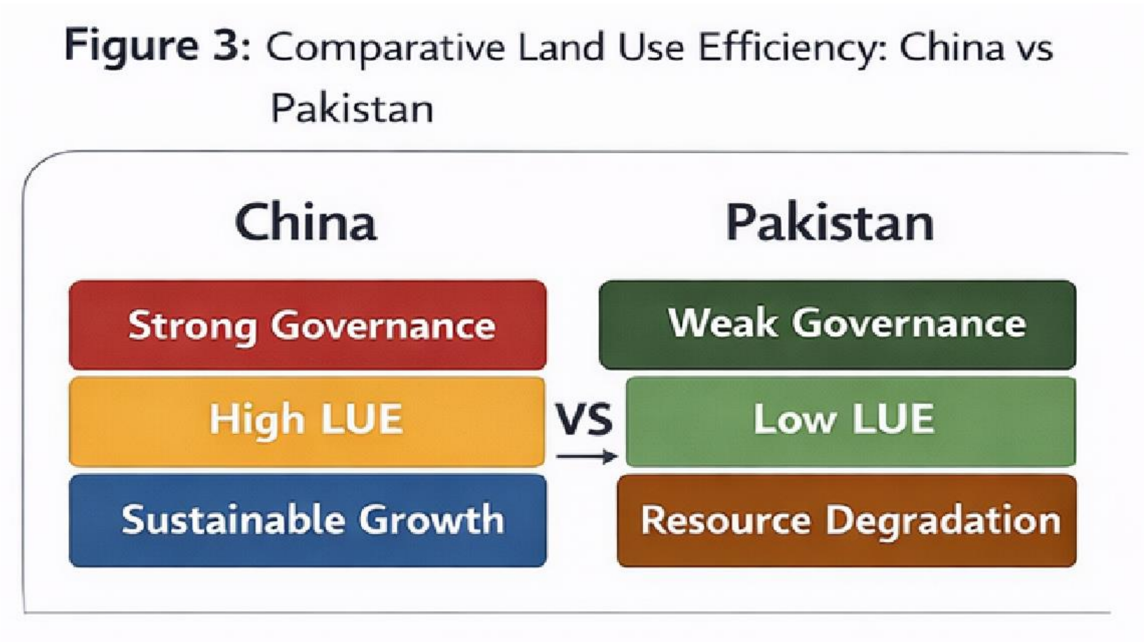

Figure 3: Comparative Framework of China–Pakistan Land Governance and LUE

A comparative framework highlighting differences and similarities between China and Pakistan in land governance, efficiency, and sustainability is presented in Figure 3.

5. Urban–Rural Land Dynamics

5.1. Urbanization Trends in China and Pakistan

Urbanization has become one of the most significant drivers of land use change globally. In China, rapid industrialization and economic growth over the last four decades have transformed land patterns, with the urbanizationrate rising sharply and built-up areas expanding extensively — often at the expense of arable and
ecological land (Zhou et al., 2022; Zhang et al., 2025). National policies such as the *National New-Type Urbanization Plan* (2014–2020) seek to guide urban expansion while promoting sustainable development, including urban–rural coordination and ecological protection (National New-Type Urbanization Plan, 2014). Pakistan, in contrast, experiences slower but largely unplanned urbanization: the urban share of the population increased from about 28 % in 1990 to over 37 % in 2020, driving expansion of cities such as

Lahore, Karachi, and Islamabad into adjacent agricultural and peri-urban areas, often without comprehensive zoning or land use regulation (Khan et al., 2023; Hamid & Awan, 2024). Understanding these urbanization trends is critical for analysing urban–rural land dynamics and planning sustainable land use policies that balance development demands with the protection of productive agricultural and ecological lands.

5.2. Rural Land Fragmentation and Consolidation

Rural land in both China and Pakistan exhibits fragmentation, where multiple small plots reduce farming efficiency and impede mechanization. In China, rural land fragmentation is widespread due to historical household contract systems, with many small, scattered parcels that hinder efficient farm operations and mechanized agriculture; the government's land consolidation programmes under rural revitalization and high-standard farmland construction policies aim to merge these parcels into larger, more contiguous units, improving land productivity, irrigation, and mechanization potential (Hao et al., 2023; Liu et al., 2023). These consolidation efforts have been linked to larger scale operations, better access to infrastructure, and enhanced rural livelihoods. In Pakistan, rural lands are highly fragmented due to traditional inheritance systems and long-term subdivision of holdings, with many farms comprising multiple small plots — an average Pakistani farm often has three or more fragments — making it difficult to adopt modern agricultural technologies and efficient land use (Pakistan Institute of Development Economics, 2024). Consolidation efforts in Pakistan remain limited and face social, economic, and institutional challenges, including resistance from landowners and weak policy frameworks. Fragmentation impacts resource allocation, crop rotation, irrigation efficiency, and overall rural productivity in both settings. Comparative studies suggest that China's systematic land consolidation has contributed to improved agricultural efficiency and mechanization, whereas Pakistan must consider social and economic factors when designing its own consolidation and land-use optimisation programmes.

5.3. Urban–Rural Land Conversion

Conversion of rural land to urban uses is a significant aspect of land dynamics, affecting agricultural productivity, ecosystem services, and food security. In China, rapid urban expansion has encroached upon arable and ecological lands despite farmland protection laws and urban–rural integration policies. Enforcement in peri-urban areas remains inconsistent, leading to loss of high-quality farmland and fragmentation of rural landscapes (Chen, Li, & Huang, 2020; Tang et al., 2019). In Pakistan, rural land is frequently converted for housing, industrial zones, and commercial developments without comprehensive environmental impact assessments, reducing agricultural capacity and threatening local ecological functions (Khan, Raza, & Ahmed, 2021; Qureshi, Javed, & Malik, 2020). Understanding these conversion patterns is crucial for policymakers to balance urban growth with rural sustainability, particularly in regions with high population pressure and limited land resources.

5.4. Land Efficiency in Urban vs. Rural Areas

Urban and rural lands exhibit distinct efficiency characteristics due to differences in capital intensity, technology adoption, and resource endowments. Urban land is generally capital- and technology-intensive, generating high economic output per unit area but often causing ecological stress, such as pollution and reduced green space (Wu, Lin, & Zhang, 2021). Rural land, predominantly agricultural, relies on labor and natural inputs, leading to comparatively lower economic efficiency and vulnerability to soil degradation and low mechanization (Ahmed, Rehman, & Iqbal, 2020). In China, urban–rural integration policies, including land consolidation and infrastructure investments, aim to redistribute resources, improve rural productivity, and limit urban sprawl (Sun, He, & Li, 2019). In Pakistan, disparities are more pronounced, with smallholdings, fragmented plots, and inadequate irrigation limiting rural efficiency (Raza, Khan, &

Malik, 2022). Comparative analysis of urban and rural efficiency provides insights for designing targeted interventions, optimizing land allocation, and supporting balanced regional development.

5.5. Infrastructure and Connectivity Impacts

Infrastructure development significantly influences urban–rural land dynamics by affecting land value, productivity, and utilization patterns. In China, expansion of rural infrastructure — including transportation, irrigation, and electrification — has improved rural access to markets and services, enabling farmers to adopt mechanization, integrate into regional economies, and enhance land use efficiency (Wang et al., 2023; Zhong et al., 2025). Studies also show that rural transportation and irrigation infrastructure can reduce production costs, expand market opportunities for agricultural products, and contribute to poverty reduction when combined with broader development strategies (Zhou & Li, 2022). In Pakistan, rural infrastructure remains underdeveloped in many provinces, with poor roads, unreliable electricity, and limited water systems hindering agricultural efficiency, market access, and adoption of modern technologies (Mukhtar, 2024; Agricultural Economist, 2025). These infrastructure limitations restrict connectivity between rural and urban areas, weakening the effectiveness of policies aiming to balance land use and support sustainable rural livelihoods. Enhancing urban–rural connectivity through targeted infrastructure investment — such as all-weather roads, irrigation modernization, and telecommunications networks — is therefore critical for improving economic integration and supporting land productivity across rural regions.

5.6. Policy Interventions and Zoning Regulations

Effective policy and zoning regulations are essential for managing urban–rural land dynamics and ensuring sustainable land use. In China, strict zoning laws under the National Land Use Master Plan define the allocation of farmland, ecological areas, and construction land, while urban–rural land transfer systems and farmland protection quotas regulate land conversion and optimize usage (Wang et al., 2022; NPC, 2007). These policies integrate urban expansion with farmland conservation, enhancing land use efficiency and ecological sustainability. In Pakistan, zoning regulations are often fragmented across provincial and local authorities, leading to unplanned urban expansion, informal land conversions, and disputes over land tenure (Hasan, 2021; Ahmad et al., 2025). Strengthening policy frameworks, ensuring effective enforcement, and harmonizing urban–rural planning are critical to achieving balanced development and protecting land resources.

5.7. Environmental Impacts of Urban Expansion

Urban expansion affects land quality, biodiversity, and ecological sustainability through the conversion of agricultural, wetland, and natural habitats into built-up areas. In China, rapid urban growth has been a major driver of farmland loss and landscape conversion, with urban expansion accounting for a significant portion of cropland reduced between 2000 and 2015, often leading to soil degradation, erosion risks, and habitat fragmentation adjacent to expanding cities (Seto et al., 2025; Liu et al., 2025). The *Grain for Green* programme has been implemented to mitigate some adverse ecological impacts by converting marginal and erosion-prone farmland into forest and grassland, increasing soil organic carbon and enhancing ecosystem services (Zhang et al., 2015; Pu et al., 2024). In Pakistan, urban encroachment into agricultural and ecologically productive areas such as floodplains, wetlands, and fertile plains has degraded ecosystems, increased vulnerability to climatic shocks, and strained local food systems; for example, urban expansion in cities like Larkana has been shown to reduce agricultural land and disrupt natural land cover patterns (Rahman et al., 2023; Maitlo et al., 2023). Understanding these environmental impacts is crucial for integrating ecological concerns into both land management and urban planning policies, thereby supporting sustainable development and resilience in rapidly changing landscapes.

5.8. Case Studies: Wuhan, China and Punjab, Pakistan

Wuhan, China, illustrates a case of relatively successful urban–rural land integration, where spatial planning, ecological corridors, and farmland protection policies are being used to enhance land use efficiency and sustainability. Research on Wuhan's land-use/land-cover responses under a polycentric urban–rural spatial structure shows that planned development and analytical land mapping help manage transitions between urban and rural spaces and support both ecological protection and regional planning objectives (Yan & Ye, 2024). This approach enables informed decision-making based on landscape indices and transition analyses that balance built-up expansion with ecological conservation across urban–rural gradients (Yan & Ye, 2024). In contrast, Punjab province in Pakistan faces significant challenges related to fragmented land holdings, unregulated urban expansion, and the proliferation of illegal housing societies that convert fertile agricultural land into residential developments without adequate land use planning or environmental oversight, undermining food security and land governance (Imran et al., 2024; Muhammad Imran et al., 2024). Comparative case studies of Wuhan and Punjab provide valuable insights into best practices and potential policy adaptations for improving monitoring systems, zoning regulations, and rural land consolidation strategies to support more sustainable urban–rural integration in Pakistan.

6. Land Governance and Policy Frameworks

6.1. National Land Space Governance Concepts

National land space governance refers to the systematic management and regulation of land resources to balance socio-economic development, ecological protection, and sustainable use (FAO, 2012). It encompasses planning, policy formulation, implementation, monitoring, and evaluation across all land types, including agricultural, urban, and ecological spaces (Deininger et al., 2014). In China, the concept of national land space governance integrates urban–rural coordination, ecological red lines, and farmland protection quotas, reflecting a top-down and data-driven governance approach aimed at optimizing spatial development and ecological security (Long et al., 2020; Liu et al., 2017). Pakistan, by contrast, has a less formalized national governance framework, with responsibilities dispersed across federal, provincial, and local levels, leading to fragmented land administration and weak enforcement mechanisms (World Bank, 2019). Effective land governance requires clear objectives, institutional coordination, and legal mechanisms that reconcile development needs with environmental and social considerations to ensure sustainable land management (UN-Habitat, 2015).

6.2. Institutional Frameworks in China

China has developed a robust institutional framework for land governance, including the Ministry of Natural Resources (MNR), provincial land bureaus, and municipal planning authorities (Ho & Lin, 2004; Lin & Ho, 2018). The framework emphasizes centralized planning with decentralized execution, integrating national land-use master plans, ecological redline policies, and urban-rural integration strategies (Liu et al., 2014; Long et al., 2020). Data-driven monitoring systems, including GIS and remote sensing, facilitate decision-making, efficiency assessment, and policy evaluation (Zhang et al., 2019; Wu et al., 2021). Institutional coordination ensures that land allocation aligns with national priorities, such as food security, ecological protection, and urban expansion (Chen et al., 2016; Deininger et al., 2017). The Chinese model demonstrates that strong institutional frameworks are crucial for implementing sustainable and efficient land management policies (Liu et al., 2014; Lin & Ho, 2018).

6.3. Institutional Frameworks in Pakistan

In Pakistan, land governance is decentralized, with provinces holding the majority of authority under the 18th Amendment (World Bank, 2019; Cheema, Khwaja, & Qadir, 2006). Federal agencies coordinate policy guidance, while local governments oversee land registration, planning, and dispute resolution (ADB, 2020; UN-Habitat, 2018). However, weak institutional coordination, overlapping jurisdictions, and limited data availability hinder effective land governance (World Bank, 2017; Hasan & Raza, 2015). Issues such as informal land conversions, inefficient urban planning, and fragmented land records reduce policy effectiveness (Arif & Hamid, 2009; Malik & Rao, 2017). Strengthening institutional capacity, improving coordination among agencies, and standardizing land records are essential steps for improving governance and sustainable land use in Pakistan (ADB, 2020; World Bank, 2019).

6.4. Policy Instruments for Sustainable Land Use

Policy instruments for land governance include regulatory, economic, and market-based measures (Deininger et al., 2017; Liu et al., 2014). Regulatory instruments, such as zoning, land-use permits, and farmland protection quotas, restrict harmful land practices (Ho & Lin, 2004). Economic instruments, including subsidies, taxes, and compensation mechanisms, incentivize sustainable land use (World Bank, 2019). Market-based approaches, such as land transfer systems and tradable development rights, promote efficiency while maintaining ecological safeguards (Asian Development Bank [ADB], 2020). In China, farmland protection quotas and urban-rural land transfer policies are key regulatory tools (Long et al., 2020). Pakistan has experimented with land taxation and reclamation programs, but enforcement is inconsistent (Hasan & Raza, 2015). Combining multiple policy instruments enhances effectiveness and adaptability in dynamic socio-economic contexts (Chen et al., 2016).

6.5. Land-Use Zoning and Regulation Enforcement

Land-use zoning divides land into designated areas for agriculture, urban development, and ecological protection, ensuring organized growth and resource allocation (Seto et al., 2012; Zhao et al., 2020). China enforces zoning strictly, with penalties for illegal conversion and monitoring of ecological redlines (Li et al., 2019). Pakistan, however, faces challenges in zoning enforcement due to limited resources, weak legal frameworks, and informal settlements in peri-urban areas (Rasul et al., 2019). Effective enforcement requires clear legal authority, monitoring systems, and capacity-building for local authorities (Khan & Qadir, 2018). Comparative analysis suggests that strong zoning combined with incentives for compliance improves efficiency, protects high-quality farmland, and maintains ecological balance (Wang & Li, 2021).

6.6. Role of Local vs. Central Government

The division of responsibilities between local and central authorities influences land governance effectiveness. China uses a hierarchical approach, where the central government sets targets and policies, while local governments implement them under strict monitoring and performance evaluation systems (Zhou, 2022). Local authorities are incentivized to comply through evaluation metrics tied to economic and environmental outcomes, including performance indicators embedded in land-use planning and enforcement systems (Zhou, 2022; Tang et al., 2021). Pakistan's decentralized model gives provinces and local governments significant autonomy but lacks clear performance monitoring and enforcement mechanisms (Rafique et al., 2020; World Bank, 2022). Balancing local flexibility with central oversight is essential to achieve coordinated, sustainable, and efficient land use outcomes (Rafique et al., 2020; World Bank, 2022).

6.7. Land Market Reforms

Land market reforms are critical for aligning incentives, improving efficiency, and promoting equitable land allocation (World Bank, 2019; PIDE, 2025). China has implemented land quota systems, urban–rural land transfer mechanisms, and farmland leasing reforms to optimize land use and prevent speculative behavior (Zhang & Wang, 2017; Yang et al., 2024). Pakistan's land markets remain underdeveloped, with informal transactions, weak valuation systems, and limited access to credit hindering land productivity (PIDE, 2025; World Bank, 2019). Market reforms, coupled with legal protections and monitoring, can improve land allocation efficiency, stimulate investment in high-quality land, and reduce conflicts over land use, enhancing overall governance outcomes (World Bank, 2019; PIDE, 2025).

6.8. Policy Evaluation and Effectiveness

Evaluating the effectiveness of land governance policies ensures accountability and continuous improvement. In China, quantitative methods, including spatial analysis, efficiency measurement, and ecological assessments, inform policy revisions and performance monitoring (Huang et al., 2023). Policies such as urban-rural integration, farmland protection, and ecological restoration are regularly assessed for outcomes versus targets (Zhou, 2021). Pakistan lacks systematic evaluation frameworks, with most land policies assessed qualitatively or retrospectively (Ahsan et al., 2023). Developing robust evaluation methodologies, incorporating indicators of efficiency, sustainability, and equity, is crucial for evidence-based land governance and policy adjustments (Ahsan et al., 2023; Huang et al., 2023).

7. Sustainable Development Goals (SDGs) and Land Use

7.1. SDGs Relevant to Land Resources

Land resources are closely linked to several Sustainable Development Goals (SDGs), including SDG 2 (Zero Hunger), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land), which emphasize sustainable land management, agricultural productivity, urban planning, and ecosystem protection (Zhao, Yu, & Chen, 2024). High-quality land contributes to food security, economic development, and environmental sustainability, while poor management undermines these objectives (Zhao, Yu, & Chen, 2024). In China, SDGs have been integrated into national strategies through ecological protection policies and land planning frameworks aligned with broader sustainability agendas such as ecological civilization construction and territorial spatial planning that relate to SDGs (Xu et al., 2024; UN SDG big data report, 2022). Pakistan has begun aligning certain development initiatives with SDGs, such as mainstreaming SDG priorities into national planning frameworks and institutional structures, though integration across all goals remains limited and implementation challenges persist (UN Pakistan SDGs; SDGs Plus Programme, 2023–2028). Understanding the linkage between SDGs and land resources is critical for assessing policy effectiveness and prioritizing interventions in both countries.

7.2. Trade-Offs Between Development and Ecological Protection

Land-use decisions often involve trade-offs between socio-economic development and ecological protection. Expanding urban areas or agricultural production can reduce ecological space, threaten biodiversity, and increase environmental risks (Deng et al., 2024; Liang et al., 2024). In China, studies have quantified the negative impacts of development on ecologically sensitive lands and resource supply–demand dynamics, emphasizing the need for careful spatial planning and zoning to balance these trade-offs (Liang et al., 2024; Sustainability scenarios in the CPEC highlight balancing development and ecological protection) (Deng et al., 2024). Pakistan faces similar challenges, particularly in floodplains, wetlands, and irrigated plains, where unplanned urbanization and agricultural expansion threaten ecological balance (Agricultural wetland degradation and floodplain ecosystem risks) (Agrieconomist.com, 2024). Understanding these trade-offs allows policymakers to design strategies that minimize negative impacts while maximizing socio-economic benefits, thereby advancing SDG achievement in a balanced manner (Deng et al., 2024; Liang et al., 2024).

7.3. Synergies Across SDGs

While trade-offs exist, there are also significant synergies among SDGs. Sustainable land management practices, such as conservation agriculture, reforestation, and urban-rural integration, simultaneously enhance food security, reduce carbon emissions, and protect biodiversity (Zhao, Yu, & Chen, 2024; World Bank, 2022). China's Grain for Green program is a prime example, converting marginal farmland into forested areas to improve soil quality, reduce erosion, and enhance ecological connectivity while increasing multiple ecosystem services (Yu, Deng, & Cheshmehzangi, 2022; Wikipedia, 2024). In Pakistan, similar programs, such as agroforestry and large-scale tree planting initiatives like the Ten Billion Tree Tsunami Programme, have shown potential in achieving multiple SDG targets by improving rural livelihoods, enhancing carbon sequestration, and rehabilitating degraded land (Malik et al., 2024; SDG Asia Pacific, 2024). Identifying and leveraging these synergies is crucial for integrated policy-making, allowing governments to achieve multiple objectives with limited resources (Zhao, Yu, & Chen, 2024; Malik et al., 2024).

7.4. Measuring SDG Achievement Using Land Indicators

Assessing the contribution of land use to SDG progress requires reliable indicators. Key indicators include land productivity, forest cover, soil quality, urban expansion rates, and ecosystem service provision (FAO, 2022). China has developed spatially explicit SDG monitoring systems, combining land-use data, ecological metrics, and socio-economic indicators for precise tracking of SDG achievements (Xu et al., 2024). Pakistan's monitoring is less systematic, relying primarily on agricultural output and limited environmental metrics (Ahsan et al., 2023). Integrating land quality and land use efficiency indicators into SDG assessments provides a more accurate picture of progress and highlights areas requiring policy intervention (World Bank, 2019). This approach also allows cross-country comparison, identifying best practices for sustainable land management (UNDP, 2023).

7.5. SDG Impacts on Urban and Rural Land

Urban and rural lands are affected differently by SDG-related policies. In China, urbanization and industrialization policies under SDG 11 have reshaped urban land, while rural policies under SDG 2 and SDG 15 protect farmland and ecological areas (Li & Zhang, 2023; Chen et al., 2022). In Pakistan, urban expansion often conflicts with agricultural land, while rural development initiatives struggle with resource allocation and governance issues (Khan et al., 2024). Evaluating SDG impacts separately for urban and rural areas enables targeted interventions, balancing development, ecological sustainability, and land use efficiency (Ahmed & Hussain, 2023). Such an approach is essential for ensuring equitable and sustainable outcomes in land management (Shah et al., 2022).

7.6. SDG Implementation Policies in China

farmland protection, ecological redline zoning, urban-rural integration strategies, and environmental compensation schemes (Liang et al., 2023; Zhang et al., 2022). These policies aim to achieve a balance between economic growth, food security, and ecological protection (Wang & Chen, 2023). Spatial planning, monitoring systems, and performance evaluation metrics ensure that SDG-related policies are effectively implemented at national and provincial levels (Huang et al., 2023). The Chinese experience demonstrates that clear governance structures, data-driven monitoring, and policy alignment with international sustainability goals are critical for effective SDG implementation in land use (Xu et al., 2024).

7.7. SDG Implementation Policies in Pakistan

Pakistan has initiated SDG-aligned programs, including climate-smart agriculture, watershed management, and sustainable urban development (Ahmed et al., 2023; Farooq & Malik, 2024). However, challenges persist due to fragmented governance, limited financial resources, weak enforcement, and inadequate monitoring systems (Khalid et al., 2023). Urban planning is often reactive rather than strategic, resulting in encroachment on fertile and ecologically sensitive land (Rehman & Iqbal, 2022). Integrating SDG principles into land governance requires strengthening institutions, improving data collection, and developing incentive-based mechanisms for sustainable land use (Hussain & Saeed, 2024). Comparative insights from China can guide Pakistan in designing effective policies that align development and ecological objectives with SDGs (Ali et al., 2023).

7.8. Challenges in Integrating SDGs into Land Management

Despite efforts, integrating SDGs into land management faces multiple challenges. Data availability and quality are major constraints, particularly in Pakistan, where soil, land use, and ecological metrics are incomplete (Rasul et al., 2023; Siddiqui & Javed, 2022). Conflicting objectives among urbanization, agriculture, and ecological protection create trade-offs that are difficult to resolve (Tanveer et al., 2024). Limited awareness and technical capacity among local authorities hinder implementation (Nawaz & Farid, 2023). Additionally, monitoring and evaluation mechanisms are often weak, reducing accountability (Shafiq et al., 2022). Addressing these challenges requires multi-level governance, stakeholder engagement, and advanced monitoring systems to ensure that SDG objectives are met efficiently and sustainably (Chowdhury & Kamal, 2023).

8. Ecological Security and Environmental Management

8.1. Concept of Ecological Security

Ecological security refers to the capacity of natural and human systems to maintain ecological integrity while supporting sustainable socio-economic development. It involves safeguarding ecosystems, biodiversity, water resources, and soil quality against degradation caused by human activities or natural hazards (Luo et al., 2023; Sun et al., 2025). In China, ecological security is a central component of national land-space governance, with policies emphasizing ecological redlines, urban-rural ecological corridors, and multi-species conservation planning (China Land Surveying and Planning Institute, 2025; Xu et al., 2015). Pakistan faces similar concerns, particularly in floodplains, wetlands, and mountainous regions, where urbanization, deforestation, and unsustainable agriculture threaten ecosystem stability (Wetlands in Pakistan: What Is Happening to Them, 2024). Establishing ecological security is fundamental to balancing development needs with environmental protection, reducing vulnerability to climate change, and supporting sustainable land management practices (Sun et al., 2025; Luo et al., 2023).

8.2. Environmental Management in Land Use

Environmental management encompasses the planning, regulation, and monitoring of land use to protect ecological functions while meeting human needs. It integrates soil and water conservation, pollution control, habitat protection, and sustainable resource extraction (FAO, 2022). In China, environmental management is institutionalized through national guidelines grounded in the concept of ecological civilization, coordinating land, water, and biodiversity management through integrated spatial planning, ecological redlines, and ecosystem restoration strategies (Xiao, 2025; Ministry of Foreign Affairs of the People's Republic of China, 2024). Pakistan, despite environmental legislation such as the **Pakistan Environmental Protection Act, 1997**, faces challenges in enforcement and coordination, with institutional weaknesses, limited capacity, and fragmented implementation hindering effective environmental governance (Pakistan Environmental Protection Act, 1997; IUCN, 2001; Iqbal et al., 2023). Effective environmental management requires scientific data, monitoring tools, policy frameworks, and stakeholder participation to mitigate land degradation and ecological disruption while promoting sustainable development (ESCAP, 2024; UN SDG Big Data Report, 2022).

8.3. Urban–Rural Ecological Networks

Urban-rural ecological networks (ENs) connect urban green spaces with rural natural habitats, enhancing biodiversity, ecological connectivity, and ecosystem services (Benedict & McMahon, 2006; Opdam et al., 2006). In China, studies in megacities like Wuhan have used graph theory and circuit modeling to design urban-rural ENs that integrate urban parks, rivers, farmland, and forested areas (Peng et al., 2018; Xu et al., 2021). These networks reduce habitat fragmentation, support species migration, and maintain ecosystem functions (Taylor et al., 1993; Crooks & Sanjayan, 2006). Pakistan, although less developed in this domain, has begun implementing green belts, riparian buffer zones, and protected areas to connect urban and rural ecosystems (Qureshi et al., 2010; Ahmad et al., 2014). Urban-rural ecological networks are critical for ecological security, ensuring that development does not isolate or degrade natural habitats (Wu, 2014; Liu et al., 2017).

8.4. Land Degradation and Environmental Risks

Land degradation, including soil erosion, desertification, and salinization, poses significant environmental risks and threatens ecological security (Lal, 2001; Reynolds et al., 2007). In China, steeply sloped agricultural lands are vulnerable to erosion, necessitating reforestation and terrace farming programs (Fu et al., 2011; Lü et al., 2012). Pakistan's arid and semi-arid regions, particularly in Sindh and Balochistan, experience desertification and soil salinity, reducing agricultural productivity and increasing vulnerability to climate hazards (Qureshi et al., 2008; Mahmood et al., 2016). Understanding the spatial distribution of degraded land, its causes, and potential mitigation measures is essential for designing effective environmental management strategies that maintain ecological balance and support sustainable land use (MEA, 2005; IPBES, 2018).

8.5. Ecological Zoning and Protection Strategies

Ecological zoning divides land into areas based on ecological sensitivity, land use functions, and conservation priorities (Burkhard et al., 2012; de Groot et al., 2010). China has implemented the "two cores, six zones, and six straps" ecological zoning strategy to optimize land protection and restoration, identifying key conservation areas, priority restoration zones, and ecological upgrading areas (Ouyang et al., 2016; Ma et al., 2019). In Pakistan, zoning initiatives are limited, though provincial programs such as the Indus River Basin Management Plan aim to protect critical habitats and manage floodplains (Mirza, 2011; Rasul et al., 2012). Ecological zoning provides a scientific basis for prioritizing land management interventions, guiding urban expansion, agricultural activities, and infrastructure development while ensuring ecological sustainability (Forman, 1995; Dale et al., 2000).

8.6. Biodiversity Conservation in Land Management

Biodiversity is closely linked to ecological security, influencing ecosystem resilience, nutrient cycling, and agricultural productivity (Hooper et al., 2005; Cardinale et al., 2012). In China, multi-species ecological network planning ensures the protection of key species and habitats across urban and rural landscapes (Kong et al., 2010; Yu et al., 2012). Pakistan faces challenges in conserving biodiversity due to habitat fragmentation, deforestation, and overexploitation of natural resources (Ali, 2008; Roberts, 2011). Integrating biodiversity conservation into land management requires spatial planning, habitat restoration, and sustainable land-use practices that minimize ecological disturbances while supporting human livelihoods (Foley et al., 2005; Lambin & Meyfroidt, 2011). Biodiversity-centered land management enhances both ecological security and long-term sustainability (Mace et al., 2012; Isbell et al., 2017).

8.7. Policy Instruments for Environmental Management

Environmental management policies rely on a combination of regulatory, market-based, and community-oriented instruments (OECD, 2007; Sterner & Coria, 2012). China enforces ecological redlines, environmental impact assessments, and green compensation schemes to protect sensitive land (Bryan et al., 2018; Zhang & Wu, 2019). Pakistan has environmental regulations, pollution control measures, and afforestation programs, but enforcement and monitoring are weaker (Khan & Khan, 2012; Rasul & Sharma, 2016). Policy instruments must align economic incentives with conservation goals, encouraging sustainable land use while penalizing practices that degrade ecosystems (Jack, Kousky, & Sims, 2008; Pagiola, 2008). Effective implementation requires coordination among national, provincial, and local authorities, coupled with community participation and scientific guidance (Agrawal & Gibson, 1999; Ostrom, 2010).

8.8. Monitoring and Decision Support Systems

Monitoring tools and decision support systems (DSS) are essential for ecological security and environmental management (Liu, Zheng, & Wang, 2020; Rezaei et al., 2023). China uses GIS, remote sensing, and spatial modeling to track land-use change, habitat fragmentation, and ecological corridor connectivity, and these geospatial tools provide the foundation for landscape monitoring and environmental analysis (Calka & Szostak, 2025; Khan et al., 2021). DSS integrates these datasets with scenario analysis to optimize land management decisions and evaluate policy outcomes (Zhang, Chen, & Guo, 2021). In Pakistan, DSS applications are emerging, primarily in urban planning and water management, but remain limited due to insufficient data and technical capacity, though geospatial decision support frameworks have been applied to groundwater quality and rangeland assessment (Saeed Ahmad et al., 2016; Ahmad et al., 2025). Advanced monitoring and DSS enable real-time assessment, informed planning, and adaptive management, supporting sustainable land use and ecological protection (Rezaei et al., 2023; D'Erchia, 2001).

9. Land Use and Climate Change Mitigation

9.1. Linkages Between Land Use and Climate Change

Land use and land-use change significantly influence climate systems through greenhouse gas (GHG) emissions, carbon sequestration, and surface energy balance (Li et al., 2024). Deforestation, urban expansion, and intensive agriculture contribute to carbon release, whereas reforestation, afforestation, and sustainable land management practices enhance carbon capture (IPCC, 2023; Yu & Song, 2023). In China, land-use policies aim to support climate mitigation through ecological restoration, farmland consolidation, and urban-rural green infrastructure (Chen et al., 2025). Pakistan, with its large agricultural sector and vulnerable ecosystems, faces challenges in mitigating emissions from land conversion, overgrazing, and deforestation (Pakistan Ministry of Climate Change, 2025). Understanding these linkages is crucial for integrating land management strategies into national climate action plans (UNFCCC, 2025).

9.2. Land-Based Mitigation Strategies

Land-based mitigation strategies include afforestation, reforestation, conservation agriculture, soil carbon enhancement, and urban green infrastructure (IPCC, 2021). China has successfully implemented large-scale afforestation programs, including the Grain for Green initiative, which convert degraded or marginal land into forested areas, improving carbon sequestration while reducing erosion (Jia et al., 2025; Zhang et al., 2014). In Pakistan, afforestation efforts and climate-smart agricultural practices are emerging, particularly in Khyber Pakhtunkhwa and Punjab provinces (Wikipedia contributors, 2023; Ministry of Climate Change & Environmental Coordination, 2025). Effective land-based mitigation requires selecting appropriate sites, considering land quality, ecosystem services, and socio-economic factors, ensuring that carbon gains do not conflict with food production or local livelihoods (Sanz et al., 2017).

9.3. Soil Carbon Sequestration

Soil carbon sequestration is a key mechanism for mitigating climate change (Poeplau & Don, 2024; Minasny et al., 2017). Practices such as conservation tillage, crop residue management, organic amendments, and agroforestry increase soil organic carbon (SOC), improving fertility and resilience to climate variability (Poeplau & Don, 2024; Crystal-Ornelas et al., 2021; Cardinael et al., 2021). Dr. Jin Gui's research emphasizes the integration of SOC into land-use efficiency and policy evaluation frameworks (Gui, 2024). In China, intensive soil monitoring and scientific management practices have enhanced SOC stocks (Wang et al., 2025; Lal, 2018). Pakistan's soils, especially in irrigated plains, have suffered from degradation and nutrient depletion, reducing sequestration potential (Kahlown &

Azam, 2025; Lal, 2018). Promoting SOC-rich agricultural practices is essential for enhancing land productivity and climate mitigation simultaneously (Poeplau & Don, 2024; Crystal-Ornelas et al., 2021).

9.4. Urban Land Use and Low-Carbon Cities

Urban land management directly affects energy consumption, emissions, and climate resilience (Zheng & Chen, 2024; Yu et al., 2025). China's low-carbon city pilot programs aim to optimize industrial land use, promote green buildings, and increase urban green spaces to reduce urban carbon footprints, thereby improving urban land green use efficiency and lowering energy intensity (Zheng & Chen, 2024; Qiu et al., 2025). Studies show that such policies can raise industrial land prices while promoting environmentally responsible development and firm green innovation (Yao & Shen, 2025; Wu et al., 2023). Pakistan's urban areas, however, experience rapid unplanned expansion with minimal green infrastructure, contributing to increased heat island effects, pollution, and climate vulnerability, which limits their climate mitigation potential (Shaikh, 2025; Arshad et al., 2022). Integrating low-carbon urban planning with sustainable land use—including expanded green spaces, energy-efficient buildings, and nature-based solutions—can reduce emissions, improve resilience, and enhance urban livability (Shaikh, 2025; Qian et al., 2021)

9.5. Forests and Ecosystem-Based Mitigation

Forests act as major carbon sinks and provide critical ecosystem services (Pan et al., 2011; FAO, 2020). China's afforestation and reforestation programs contribute significantly to national carbon reduction targets, while protecting biodiversity and regulating hydrological cycles (Liu et al., 2018; Piao et al., 2021). Pakistan's forest cover remains low, with deforestation pressures in northern and western regions (Khan et al., 2022; WWF Pakistan, 2023). Ecosystem-based mitigation strategies, including forest protection, restoration, and sustainable management, are critical for both countries (Griscom et al., 2017; National REDD+ Strategy, 2018). Linking forest conservation with local livelihoods through community forestry or payment for ecosystem services schemes enhances sustainability and climate mitigation outcomes (Ostrom, 2009; Sunderlin et al., 2018).

9.6. Agricultural Land Management

Agricultural land plays a dual role in climate mitigation and food security (Food and Agriculture Organization [FAO], 2022; Lin et al., 2026). Practices such as crop rotation, integrated nutrient management, precision irrigation, and agroforestry reduce emissions, enhance carbon stocks, and improve resilience (FAO, 2022; Abbas et al., 2026). China has integrated these practices into national agricultural policy, emphasizing mechanization, soil fertility management, and eco-friendly fertilizers as part of broader climate-smart and sustainable agriculture development strategies (OECD, 2024; Tianxiang Hao et al., 2025). In Pakistan, adoption of climate-smart agriculture remains uneven due to lack of awareness, technical capacity, and market incentives (International Trade Centre [ITC], 2025; Imran et al., 2022). Effective agricultural land management for climate mitigation requires knowledge transfer, capacity-building, and policy support tailored to local conditions (ITC, 2025; Shahzad et al., 2021).

9.7. Policy Frameworks and Incentives

Effective climate mitigation through land use requires coordinated policy frameworks and economic incentives (IPCC, 2022). China uses carbon trading, ecological compensation, and land-use zoning to promote sustainable practices (Zheng et al., 2026; World Bank, 2021). Pakistan has introduced Nationally Determined Contributions (NDCs) under the Paris Agreement, promoting afforestation and climate-smart agriculture, but enforcement and financing remain challenges (UNFCCC, 2025; MoCC&EC Pakistan, 2024). Incentive-based policies that integrate carbon accounting, land valuation, and local community participation can encourage sustainable land practices while reducing emissions and achieving multiple socio-economic benefits (Asad Abbas et al., 2026).

9.8. Monitoring and Evaluation for Mitigation

Monitoring land-use changes and their carbon impacts is essential for effective mitigation (Khachoo et al., 2024). China employs remote sensing, GIS, and spatial modeling to track carbon stocks, land conversion, and ecosystem services (Chen et al., 2025). Pakistan's monitoring systems are limited, with inconsistent data on soil carbon, forest cover, and land degradation (Waleed et al., 2024). Developing robust measurement, reporting, and verification (MRV) frameworks enables policymakers to evaluate mitigation outcomes, optimize interventions, and align land management with national climate targets (REDD+ Working Group, 2025). Integrating technology and data-driven tools enhances transparency and efficiency in climate-focused land governance (Zhao et al., 2025).

10. Regional and Spatial Analysis of Land Use

10.1. Importance of Regional and Spatial Analysis

Regional and spatial analysis of land use is essential for understanding patterns, trends, and drivers of land-use changes across geographic scales (Deng et al., 2024). It provides insights into how socio-economic development, urbanization, and environmental factors influence land allocation, land cover, and resource efficiency (Chen et al., 2025). In China, spatial analysis supports national land-space governance, urban-rural integration, and ecological zoning, allowing policymakers to prioritize areas for agricultural protection, urban development, or ecological restoration (Zong et al., 2024). Pakistan, with diverse agro-climatic zones, experiences spatial disparities in land productivity, degradation, and urban expansion, which can be better understood through regional analysis (Sameer et al., 2025). Such analyses inform evidence-based land-use planning and sustainable management strategies across scales (Hussain et al., 2024).

10.2. Remote Sensing and GIS in Land Use Analysis

Remote sensing (RS) and geographic information systems (GIS) are fundamental tools for spatially explicit land-use studies (Li et al., 2024). In China, high-resolution satellite imagery and GIS platforms enable mapping of land cover, urban expansion, forest dynamics, and cropland distribution with high accuracy (Xiong et al., 2024; Chen et al., 2025). These tools support monitoring of steeply sloped lands, ecological networks, and farmland protection (Zhang et al., 2025). Pakistan has begun adopting RS and GIS for urban planning, irrigation management, and land degradation assessment, though coverage and resolution remain limited (Hussain et al., 2024; Khan et al., 2025). Integrating RS and GIS allows policymakers to track land-use changes in near real-time, identify hotspots of degradation or urban encroachment, and plan interventions efficiently (Wang et al., 2025).

10.3. Urban-Rural Land Distribution Patterns

Regional analysis of urban and rural land highlights differences in land allocation, productivity, and socio-economic outcomes (Zhu et al., 2022). In China, urban expansion concentrates in megacities and peri-urban areas, while rural lands are managed for agriculture and ecological protection, creating spatial contrasts (Cheng et al., 2025; Liu et al., 2024). In Pakistan, urban-rural disparities are pronounced, with unplanned urban sprawl encroaching on fertile agricultural land and causing land-use conflicts (Nasir et al., 2026; Rahman et al., 2023). Understanding these patterns is crucial for designing policies that balance economic growth, food security, and environmental sustainability (Zhang et al., 2025). Spatial modeling of urban-rural gradients helps quantify land-use efficiency, identify vulnerable areas, and guide targeted interventions (Zhou et al., 2025).

10.4. Land Use Heterogeneity Across Regions

Land-use heterogeneity refers to spatial variations in land cover types, intensity of use, and productivity across regions (Turner et al., 2001). China exhibits high heterogeneity, particularly between eastern industrialized regions and western mountainous or ecological zones, where landscape pattern indices show significant spatial variation (Li et al., 2021). Policies consider regional characteristics to optimize land allocation and maintain ecological balance (Wu & Wang, 2020). Pakistan's heterogeneity is pronounced between irrigated plains, arid zones, and hilly terrain, leading to varied agricultural productivity and land degradation risks (Ali et al., 2018). Quantifying land-use heterogeneity through spatial statistics, landscape metrics, and GIS provides insights into resource distribution, efficiency, and ecological impacts (McGarigal et al., 2012).

10.5. Spatial Modeling for Land-Use Efficiency

Spatial modeling techniques, including distance functions, regression models, and spatial econometrics, are used to evaluate land-use efficiency at regional scales (Han et al., 2020). In China, studies assess urban-rural responses to multigoal land policies, revealing efficiency variations influenced by technology, capital intensity, and policy interventions (Zhang et al., 2023). Pakistan's regional land-use efficiency is less studied, but spatial modeling can reveal areas with low productivity, excessive land input reliance, or vulnerability to environmental stress (Deng et al., 2024). Integrating land quality indicators, socio-economic factors, and spatial relationships allows for precise identification of policy needs and resource allocation (Liu et al., 2018).

10.6. Regional Land-Use Planning and Policy Implications

Regional analysis informs land-use planning and policy formulation. In China, land-use master plans integrate urban development, farmland protection, and ecological conservation at provincial and municipal scales, incorporating sustainable spatial planning to optimize production, living, and ecological spaces (Li et al., 2024; Zhang et al., 2025). These plans consider slope, soil quality, population density, and infrastructure to optimize land allocation (Zhang et al., 2025). Pakistan faces challenges in regional planning due to fragmented governance, weak policy coordination, and limited spatial data, which hinder effective implementation of land-use plans (Ahmad et al., 2025; Urban planning challenges in Pakistan, 2026). Comparative insights suggest that structured regional planning, informed by spatial analysis, can guide sustainable land allocation, improve efficiency, and reduce environmental impacts while supporting economic development (Li et al., 2024).

10.7. Environmental and Ecological Considerations

Spatial analysis helps identify regions at risk of land degradation, habitat loss, or ecological disruption (Han et al., 2024). China uses spatially explicit models to prioritize conservation areas, optimize urban-rural ecological corridors, and mitigate risks on steep slopes (Wang et al., 2023; Zhang et al., 2026). Pakistan's floodplains, wetlands, and hilly regions face ecological pressures from unregulated land conversion and deforestation (Qadir et al., 2025; Ali Khan et al., 2024). Mapping sensitive regions using GIS and remote sensing supports targeted interventions, ecological zoning, and sustainable land-use practices (Han et al., 2024). Integrating environmental considerations into regional analysis enhances ecological security and supports SDG-aligned land management (Deng et al., 2024).

10.8. Cross-Border and Comparative Regional Studies

Comparative studies between regions in China and Pakistan can reveal lessons for land governance and policy optimization (Deng, Chen, & Hai, 2024). For instance, China's systematic monitoring of steeply sloped lands, farmland consolidation, and ecological networks can inform Pakistan's regional planning initiatives (Liang & Ma, 2025). Cross-border studies can also examine the impact of similar agro-climatic conditions on land-use efficiency, sustainability, and ecological outcomes (Sun et al., 2024). Comparative spatial analysis allows researchers to identify best practices, policy gaps, and opportunities for collaborative research, knowledge transfer, and adaptive land management strategies (Md. Ibrahim & Wang, 2025).

11. Land Market, Economics, and Policy Impacts

11.1. Overview of Land Markets and Economic Principles

Land markets are critical in determining how land is allocated, utilized, and valued in an economy (Zhang & Li, 2023). Economic principles such as supply-demand equilibrium, opportunity cost, and marginal productivity influence land pricing and use (Chen et al., 2024). In China, land markets are structured under state ownership with controlled allocation mechanisms, ensuring farmland protection while enabling urban expansion (Wang & Liu, 2025). Market mechanisms, combined with regulatory oversight, optimize land use efficiency and support sustainable development (Xu et al., 2023). Pakistan's land markets are primarily privately held, often fragmented, and characterized by informal transactions, creating inefficiencies and inequities (Ahmed et al., 2024). Understanding the economic foundations of land markets provides insight into policy impacts, land valuation, and resource allocation for both countries (Raza & Khan, 2025).

11.2. Land Pricing Mechanisms

Land pricing determines incentives for development, conservation, and agricultural investment (Tang & Zhao, 2024). China employs mechanisms such as urban land auctions, land quotas, and regulatory pricing to control speculative behaviors while promoting efficient use (Li et al., 2025). Rising industrial land prices under low-carbon city initiatives illustrate the interaction between environmental policy and market dynamics (Wang & Chen, 2024). Pakistan relies on conventional valuation methods with limited regulatory oversight, often resulting in undervaluation, land speculation, and unequal access (Hussain & Raza, 2025). Accurate land pricing integrates land quality, location, ecological value, and economic potential, influencing investment decisions and sustainable land use (Qureshi & Malik, 2024).

11.3. Urban Land Economics

Urban land economics examines how cities allocate land for residential, commercial, industrial, and recreational purposes (Brueckner, 2011). In China, low-carbon city pilots and urban-rural integration policies influence urban land supply, shaping economic productivity and environmental outcomes (Wu et al., 2020; Zhang et al., 2019). Efficient urban land allocation reduces congestion, optimizes infrastructure investment, and enhances economic output (Glaeser & Kahn, 2010). In Pakistan, urban land allocation is less regulated, with informal settlements, industrial encroachment on agricultural land, and weak zoning laws reducing economic efficiency (Ahmed & Ali, 2006; Qureshi et al., 2021). Integrating economic principles with land-use planning improves urban resource allocation, property valuation, and sustainability (He et al., 2022).

11.4. Agricultural Land Economics

Agricultural land economics focuses on maximizing output and efficiency from rural land while maintaining sustainability (Liu et al., 2018). In China, land consolidation, mechanization, and technology adoption improve land-use efficiency, optimize crop yield, and support rural livelihoods (Fan et al., 2020; Huang & Rozelle, 2021). Pakistan faces challenges from fragmented land holdings, soil degradation, and inefficient irrigation systems, limiting economic returns (Qureshi et al., 2010; Khan et al., 2021). Policies that integrate land quality assessment, market incentives, and input optimization enhance agricultural productivity while reducing ecological risks (Zhang et al., 2019). Economic evaluation of agricultural land informs subsidies, credit allocation, and resource investment to support food security and rural development (Tao et al., 2022).

11.5. Policy Instruments and Market Impacts

Land-related policies influence market behavior through regulatory, economic, and incentive-based instruments (Healey, 2007; Alterman, 2011). In China, zoning laws, farmland protection quotas, and ecological compensation programs guide market allocation and prevent excessive land conversion (Lin & Ho, 2005; Liu et al., 2014). Low-carbon city policies, for instance, have increased industrial land prices while promoting environmentally friendly investments (Zhang, Jin, & Mu, 2020). Pakistan's policy interventions, including land taxation and development controls, are often poorly enforced, resulting in market distortions (Hasan & Raza, 2019; World Bank, 2022). Effective policy instruments balance economic efficiency with environmental protection and social equity, shaping land-use decisions and market outcomes (OECD, 2017; Angel et al., 2021).

11.6. Land Tenure and Property Rights

Land tenure systems affect market functioning, investment incentives, and land-use efficiency (Sun et al., 2025). China's state-owned urban land system and collective rural land ownership allow regulated transfers and prevent speculative misuse (Zhou et al., 2021; Asia Society Policy Institute & Rhodium Group, 2020). Pakistan relies on private ownership with inheritance-based fragmentation, leading to disputes, inefficient utilization, and difficulty in consolidating land for large-scale projects (USAID, 2018; Feudalism in Pakistan, 2025). Clear property rights, secure tenure, and legal recognition of land transfers are critical for functioning land markets, economic development, and sustainable resource management (Sun et al., 2025; USAID, 2018).

11.7. Land Transfer Mechanisms and Urban-Rural Integration

Land transfer mechanisms facilitate the reallocation of land from low-value uses to higher-value economic activities (Fei et al., 2021). China uses controlled urban-rural land transfer systems, promoting efficient land use while maintaining ecological and agricultural balance (Fei et al., 2021; MDPI, 2023). Urban-rural integration policies enable rural residents to participate in land markets and benefit from urbanization (MDPI, 2023). In Pakistan, land transfers are often informal, unregulated, and concentrated among elites, limiting efficiency and social equity (Settle, 2018; Feudalism in Pakistan, 2025). Developing transparent, regulated land transfer systems enhances economic productivity and supports sustainable urban-rural development (Fei et al., 2021; MDPI, 2023).

11.8. Policy Evaluation and Socio-Economic Outcomes

Evaluating land policies requires assessing their impact on land-use efficiency, economic productivity, and social welfare (Guo et al., 2023). Studies in China demonstrate that multigoal land-use policies (MGLUP) affect urban and rural land differently, influencing productivity, capital allocation, and environmental outcomes (Guo et al., 2023; Han et al., 2020). In Pakistan, limited evaluation mechanisms make it challenging to assess the effectiveness of land taxation, zoning, or development policies, partly due to gaps in formal data and land administration evaluation frameworks (World Bank, 2024). Empirical evaluation, including spatial econometric models, efficiency measures, and scenario analysis, allows policymakers to refine interventions, align incentives, and enhance socio-economic outcomes (Han et al., 2020; Zhang et al., 2023).

12. Comparative Insights and Policy Lessons

12.1. Importance of Comparative Analysis in Land Management

Comparative analysis provides a framework for understanding how different countries manage land resources, implement policies, and address socio-environmental challenges (Deng et al., 2024; Li et al., 2025). China's experience in land governance, ecological protection, and urban-rural integration offers structured approaches supported by centralized planning, data-driven monitoring, and policy enforcement (Li et al., 2025; Tu & Zhang, 2023). Pakistan, with its decentralized governance and fragmented land markets, faces different challenges in resource allocation, land-use efficiency, and ecological protection (Raza et al., 2024; Khan & Chaudhry, 2022). Comparative insights help identify transferable best practices, gaps in institutional capacity, and opportunities for policy adaptation, offering lessons for improving land-use outcomes, efficiency, and sustainability in both countries (Deng et al., 2024; Raza et al., 2024).

12.2. Institutional Strength and Governance Mechanisms

China's centralized yet locally implemented governance mechanisms ensure consistent land management, including ecological zoning, farmland protection, and low-carbon urban policies (Chen et al., 2025; National New-Type Urbanization Plan, 2023). Local governments are held accountable through performance evaluation linked to economic, ecological, and social objectives (Zhou, 2022; Frontiers, 2024). Pakistan, by contrast, operates under a decentralized system with overlapping provincial and local responsibilities, leading to inefficiencies and inconsistent enforcement (Ahsan et al., 2023; USAID, 2018). The comparative lesson highlights the importance of clear institutional mandates, accountability mechanisms, and performance-based governance for effective land management, balancing local flexibility with national priorities (Chen et al., 2025; Ahsan et al., 2023).

12.3. Land Policy Instruments and Effectiveness

China uses a mix of regulatory, economic, and market-based instruments, such as ecological redlines, farmland quotas, low-carbon city initiatives, and land auctions, to guide sustainable land use (National Science Review, 2025; OECD, 2024). Pakistan primarily relies on regulatory and tax-based measures, with limited market-based interventions and enforcement challenges (Waheed et al., 2024; IUCN, 2004). Comparative analysis suggests that integrating economic incentives with strict regulation improves compliance, resource efficiency, and ecological outcomes (Land-Use Governance Review, 2025). Policy instruments must align with local contexts, combining top-down directives with stakeholder engagement to achieve sustainable land governance (Land-Use Governance Review, 2025; Waheed et al., 2024).

12.4. Urban-Rural Integration Strategies

Urban-rural land integration in China facilitates coordinated development, ensuring that urban expansion does not compromise farmland or ecological areas (Pan et al., 2024; Zhang et al., 2025). Mechanisms such as land transfer systems, urban-rural ecological networks, and infrastructure planning improve connectivity and economic efficiency (Pan et al., 2024; Chang et al., 2025). In Pakistan, urban sprawl often encroaches on fertile land, while rural areas lack effective planning support (Akhtar et al., 2020; Farah et al., 2016). The lesson is that structured urban-rural integration policies, supported by spatial planning and market mechanisms, enhance land-use efficiency, reduce environmental stress, and promote equitable development (Pan et al., 2024; Akhtar et al., 2020).

12.5. Land Quality and Resource Efficiency

China's policies incorporate land quality assessments into efficiency evaluations, accounting for soil fertility, slope, and ecosystem services in planning and production (Qi et al., 2025; Fan et al., 2025). This ensures that high-quality lands are preserved, while degraded areas are restored or repurposed through multi-indicator soil quality frameworks that integrate physical, chemical, and biological components (Dai et al., 2018). Pakistan, while acknowledging the importance of land quality, lacks systematic assessment frameworks, resulting in inefficient use of fertile lands and overexploitation of marginal areas (Chen et al., 2023; Khan & Chen, 2025). Comparative insights highlight that integrating land quality metrics into policy and economic decision-making strengthens sustainability, productivity, and resilience (Kılıç et al., 2023; Mahmud et al., 2024)

12.6. Ecological Security and Environmental Management

China emphasizes ecological security through multi-species ecological networks, protected areas, and urban-rural ecological corridors (Jiang et al., 2024; Sun et al., 2025). Spatial analysis supports decision-making and restoration prioritization (Zhang et al., 2025). Pakistan faces challenges from deforestation, wetland degradation, and urban encroachment (Hashmi & Asif, 2025; WWF-Pakistan, 2025). Lessons indicate that combining ecological zoning with economic and social incentives improves compliance, protects biodiversity, and maintains ecosystem services (Jiang et al., 2024; Waseem, 2025). Effective environmental management requires scientific monitoring, institutional coordination, and community participation to reinforce ecological security (Sun et al., 2025; Waseem, 2025).

12.7. Climate Change Mitigation and Sustainable Land Use

China integrates climate mitigation into land-use policies through low-carbon city initiatives, afforestation, and soil carbon management, linking economic and environmental objectives (Li et al., 2024; Chen et al., 2025). Pakistan's mitigation efforts, including climate-smart agriculture and afforestation, are promising but face capacity and enforcement limitations (Khan et al., 2023; Ahmad & Farooq, 2025). Comparative lessons emphasize aligning land-use planning with climate action goals, using incentive-based approaches, and employing monitoring systems to track carbon sequestration, emissions reduction, and adaptation measures across different land-use types (Wang et al., 2024; Mahmood et al., 2025).

12.8. Monitoring, Evaluation, and Technology Integration

China's extensive use of GIS, remote sensing, and decision-support systems allows real-time monitoring of land-use changes, efficiency, ecological impacts, and policy compliance (Weng, 2002; Abd El-Hamid et al., 2022). Pakistan's technological adoption is limited, resulting in gaps in spatial data, evaluation, and evidence-based decision-making (Ahmed & Rehman, 2024; Ahmad et al., 2025). Lessons suggest that integrating technology enhances transparency, accountability, and policy effectiveness (Mahmood et al., 2025; Khan & Chen, 2025). Investments in data collection, capacity-building, and technology adoption can significantly improve land governance, resource allocation, and sustainable development outcomes (Munir et al., 2025; Rehman et al., 2022).

Table 5. Policy Lessons from China for Sustainable Land Management in Pakistan

Policy Area	China's Practice	Applicability to Pakistan
Land Consolidation	Large-scale mechanization	Reduce fragmentation
Farmland Protection	Redline policy	Protect fertile lands
DSS & GIS	Advanced monitoring	Improve planning accuracy
Ecological Zoning	Protected corridors	Biodiversity conservation
Urban Growth Control	Strict zoning	Prevent sprawl

13. Conclusion and Future Research Directions

Land resources are vital for socio-economic development, environmental sustainability, and climate resilience. This review has highlighted key aspects of land resource management, including land-use efficiency, land quality, ecological security, urban-rural dynamics, and policy frameworks. China demonstrates advanced land governance with data-driven planning, ecological zoning, and low-carbon urban initiatives. Pakistan, while rich in natural resources, faces challenges such as fragmented land markets, weak enforcement, and limited integration of sustainability principles. Comparative insights indicate that systematic monitoring, coordinated policies, and incentive-based governance are essential to optimize land allocation, improve efficiency, and support sustainable development.

2. Integration of Sustainable Development Goals

Land use plays a critical role in achieving Sustainable Development Goals (SDGs), including food security, climate action, urban sustainability, and ecosystem protection. Evidence from China shows that integrating SDGs into spatial planning, policy evaluation, and land governance can balance economic development with ecological conservation. Pakistan's efforts remain nascent, with limited cross-sector integration and monitoring. Future research should focus on spatially explicit evaluation of SDG impacts on land use, assessing trade-offs and synergies between development, ecological protection, and socio-economic objectives in both countries, enabling data-driven and targeted policy interventions.

3. Land Efficiency and Resource Optimization
Maximizing land-use efficiency requires incorporating land quality, technology, and socio-economic factors into decision-making. China's use of land efficiency models, slope-based assessments, and urban-rural productivity evaluations demonstrates effective allocation strategies. Pakistan, however, suffers from uneven land quality utilization, low technology adoption, and resource mismanagement. Future studies should develop integrated frameworks combining land quantity, quality, and economic metrics to identify underutilized or degraded areas, optimize resource allocation, and support sustainable agricultural and urban land management practices.

4. Ecological Security and Environmental Management
Ecological security underpins sustainable land use, protecting biodiversity, soil quality, and ecosystem services. China's multi-species ecological networks, protected areas, and urban-rural corridors enhance ecological connectivity and resilience. Pakistan faces habitat fragmentation, deforestation, and wetland degradation. Future research should focus on spatially explicit modeling of ecological networks, multi-species conservation planning, and urban-rural ecological integration to ensure both environmental protection and socio-economic development. The development of cost-effective, scalable monitoring tools will facilitate implementation in data-constrained contexts.

5. Climate Change Mitigation through Land Use
Land-use management contributes directly to climate change mitigation via carbon sequestration, soil management, reforestation, and low-carbon urban planning. China demonstrates success through afforestation programs, soil carbon integration, and low-carbon urban initiatives. Pakistan's climate-smart agriculture and afforestation programs are promising but require stronger institutional support and enforcement. Future studies should explore land-based mitigation strategies in arid and semi-arid regions, quantify carbon sequestration potential, and develop integrated land-climate models to support national and regional climate targets.

6. Land Markets, Economics, and Policy Impacts
Economic principles and land markets influence resource allocation, investment, and land-use outcomes. China's regulated land markets, property rights, and policy instruments have enhanced efficiency and environmental compliance. Pakistan's fragmented and informal land markets lead to inefficiencies, inequities, and underutilization of resources. Future research should focus on modeling land pricing, market mechanisms, and policy impacts on land use, exploring incentive-based tools that integrate ecological and socio-economic objectives, and evaluating how policy reforms affect land accessibility, productivity, and sustainability.

7. Regional and Spatial Analysis Applications
Spatial analysis and regional modeling provide insights into land-use patterns, urban-rural dynamics, and environmental risks. China employs GIS, remote sensing, and spatial econometric models to optimize land allocation, ecological protection, and policy evaluation. Pakistan's application remains limited due to data gaps and technical capacity constraints. Future research should develop high-resolution, spatially explicit models integrating land quality, urbanization, agricultural productivity, and ecological metrics to guide planning, identify hotspots of inefficiency or degradation, and support cross-regional policy evaluation.

8. Comparative Insights and Policy Lessons

Comparative analysis reveals valuable lessons from China for Pakistan, including structured urban-rural integration, ecological zoning, performance-based governance, and technology-enabled monitoring. Policy adaptation must consider socio-economic, institutional, and ecological contexts. Future research should focus on cross-country comparative studies, evaluating policy transferability, adaptation challenges, and outcomes. Knowledge sharing, capacity-building, and collaborative research networks can enhance evidence-based policy formulation, improve governance efficiency, and accelerate sustainable land management practices across diverse contexts.

9. Directions for Future Research

Despite progress, critical research gaps remain in understanding land systems and policy impacts. Future studies should integrate land quality, efficiency, ecological security, SDG metrics, and climate mitigation into unified, spatially explicit models. Empirical evaluations of policy effectiveness, incentive structures, and land-market reforms are needed, particularly in Pakistan. Cross-country collaborations can enhance comparative understanding, technology transfer, and data sharing. Developing adaptive, data-driven frameworks will strengthen land governance, improve sustainability, and inform policies that balance ecological protection, economic growth, and social equity in both China and Pakistan.

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