



**LAND MANAGEMENT, ENVIRONMENT & SOLID-WASTE:
INSIDE EDUCATION AND BUSINESS IN CENTRAL ASIA
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MICRO-CREDENTIAL

LAND MANAGEMENT IN CENTRAL ASIA

6.- Rational Land Use and Efficiency

**Rational Land Use and Efficiency
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1. SUMMARY OF KEY IDEAS

Land use refers to the way humans utilize land resources for different purposes such as agriculture, industry, housing, and recreation.

It reflects the interaction between human activities and the natural environment.

Land use is influenced by physical factors (soil, climate, topography) and socio-economic factors (population, technology, policies).

The main forms of land use include agricultural, industrial, residential, commercial, transportation, forestry, and recreational uses.

Improper land use can lead to environmental problems such as land degradation, pollution, and loss of biodiversity.

Sustainable land use aims to balance economic development with environmental protection.

2. LEARNING OBJECTIVES

By studying this topic, learners should be able to:

1. Define the concept of land use and explain its importance.
2. Identify and describe different forms of land use.
3. Understand the factors influencing land use patterns.
4. Analyze the environmental impacts of various land use practices.
5. Explain the principles of sustainable and efficient land use planning.

3. INTRODUCTION

Land use is a key concept in geography, environmental science, and land management. It describes how land is utilized by humans to meet their needs, including food production, shelter, transportation, and economic activities. The pattern of land use varies across regions depending on natural conditions such as soil fertility, climate, and terrain, as well as human factors like population density, economic development, and government policies.

Over time, land use has changed significantly due to technological progress and population growth. These changes have increased pressure on land resources, often resulting in environmental challenges. Therefore, understanding the concept and forms of land use is essential for planning and managing land in a sustainable and efficient way.

4. CONCEPT OF RATIONAL LAND USE

How strategic planning, evidence-based policy, and environmental stewardship shape the world we live in — and the one we will leave behind. Rational land use is a **strategic approach** to regulating how land is used, organizing the built environment, and distributing facilities and human activities across space. It is not simply about controlling development — it is about enabling the right development, in the right place, at the right time. A structured mode of operation guiding both the formation and implementation of land-use policy. Rather than reactive or ad-hoc decisions, it demands rigorous, systematic thinking at every stage.



Figure 1.

Every city, region, and nation faces the same fundamental decision — allow development to unfold without guidance and bear the consequences, or invest in rational planning and reap the rewards of a livable, resilient, and prosperous environment.

The story of land use planning is one of hard lessons learned. Tracing its history reveals how humanity gradually recognized the need for deliberate stewardship over unmanaged growth.

Introduced football to Brazil, symbolizing one of the earliest examples of organizing land specifically for recreation and community life — a precursor to dedicated public space planning.

A Swiss advocate who championed land utilization strategies to address supply shortages and promoted decentralization, recognizing that urban concentration without planning created social and economic fragility.

The European Commission's landmark communication **COM(80)253 final** established rational land use as a cornerstone of Community Environment Policy. It articulated a clear and compelling argument: that land use, environmental health, and societal well-being are not separate issues — they are deeply and inextricably linked.

This communication set the stage for decades of integrated European planning policy, recognizing that sustainable development requires coherent frameworks that cross national boundaries and sector-specific thinking.

Every line drawn on a planning map represents a decision — a commitment to how land will be used, protected, or transformed. The history of these maps is the history of how societies have learned to think ahead, weigh competing interests, and take responsibility for the landscapes they shape.

Principles only matter when they translate into action. This chapter explores the concrete strategies, frameworks, and real-world examples that demonstrate rational land use in practice.

Brownfield regeneration is one of the most powerful demonstrations of rational land use in action. By reclaiming and revitalizing land that has already been developed — former factories, rail yards, and industrial sites — cities can meet their growth needs without consuming precious greenfield land or encroaching on natural habitats.

5. ECONOMIC EFFICIENCY OF LAND USE

Land is the foundation upon which all economic activity is built. How we allocate, develop, and manage this finite resource determines not only the productivity of our economies but the quality of life for billions of people. This presentation explores the critical relationship between land use efficiency and economic prosperity — examining the costs of misallocation, the pathways to optimization, and the policies that can transform our land resources into engines of lasting growth.

Before we can understand how to optimize land use, we must first appreciate land's unique role in economic theory and practice. Unlike capital or labor, land is fundamentally finite — it cannot be manufactured, replicated, or imported. Every city built, every crop grown, every factory constructed depends on the strategic and thoughtful allocation of this irreplaceable resource. This chapter lays the conceptual groundwork for understanding land as a powerful economic asset.

Land use efficiency is the art and science of maximizing economic output and societal benefit from a given parcel of land. It asks a deceptively simple question: are we extracting the greatest possible value — economic, social, and environmental — from every square meter at our disposal? Efficiency does not mean simply packing in as much development as possible; it means finding the highest and best use for each piece of land within its local and regional context.

Every parcel of land faces competing claims from multiple sectors of the economy. Housing needs push for residential development; growing populations require more food from agricultural land; industry

demands factory sites and logistics hubs; and conservationists argue for protecting natural habitats and ecosystem services. Balancing these demands requires sophisticated planning frameworks, transparent policy, and a clear-eyed understanding of trade-offs.

Classical economists recognized land as one of the three primary factors of production alongside labor and capital. Unlike the other two, however, land cannot be created or significantly expanded. Its supply is fixed, making its allocation among competing uses one of the most consequential economic decisions a society can make. When land is directed toward its highest-value use, entire economies flourish.

Strategic land allocation creates the physical preconditions for economic productivity. When industrial clusters are co-located with transportation infrastructure and skilled labor pools, productivity gains compound rapidly. Technology parks, innovation districts, and special economic zones all demonstrate how deliberate spatial planning can catalyze economic dynamism and drive long-run growth.

Inefficient land use is not merely an aesthetic or environmental problem — it carries profound and measurable economic costs. From the sprawling suburbs that drain municipal budgets to the misallocated farmland that suppresses agricultural productivity, the price of getting land use wrong is paid by taxpayers, businesses, and communities for generations. This chapter illuminates the many dimensions of land use inefficiency and why addressing them is an urgent economic imperative.

Urban sprawl refers to the pattern of low-density, automobile-dependent, dispersed development that has characterized the growth of many cities — particularly in North America and parts of the developing world — over the past seven decades.

Sprawl is driven by a combination of cheap land at the urban fringe, subsidized highway infrastructure, exclusionary zoning, and consumer preferences shaped by these very policies. The result is a built environment that is fundamentally inefficient from an economic standpoint.

The economic costs of sprawl are extensive and often underappreciated. Municipalities must extend water, sewer, electrical, and road infrastructure across vast distances to serve dispersed populations, dramatically increasing per-capita infrastructure costs. A 2015 report from the New Climate Economy estimated that compact, connected city development could save \$3 trillion in infrastructure spending globally over the next 15 years compared to sprawl-based scenarios.

6. SOCIAL EFFICIENCY

How we allocate, manage, and govern land is one of the most consequential decisions a society can make. From the density of our cities to the sprawl of our suburbs, from the preservation of green corridors to the siting of industry — land use shapes economic productivity, social equity, and environmental resilience for generations to come. This presentation explores the theory and practice of rational land use, drawing on foundational economic models, cutting-edge urban policy research, and the lessons of cities that have succeeded — and failed — to harness their land for the common good.

Before we can optimize land use, we must first understand what makes land uniquely important among all economic resources — and why its management sits at the very heart of social efficiency.

Land is among the most fundamental and irreplaceable resources in any economy. Unlike capital or labor, it cannot be manufactured, imported, or meaningfully substituted — its total supply is fixed, even as the demands placed upon it grow ever more complex and competing. Its use has cascading effects that reach far beyond the parcel itself.

Land underpins virtually all economic activity — from agriculture and industry to commercial real estate and residential development. The efficiency with which land is allocated determines, in large part, the productivity of an entire regional economy. Misallocated land generates deadweight losses that compound over decades.

Housing, schools, hospitals, parks, and public institutions all compete for finite land. The spatial arrangement of these uses determines who can access opportunity, how long residents commute, and whether communities are cohesive or fragmented. Poor land use planning consistently reproduces social inequality across generations.

At the heart of any serious land use framework lies a fundamental tension between two indispensable values. Getting either one wrong — or sacrificing one entirely at the altar of the other — produces outcomes that fail society in important ways. The most sophisticated land policy frameworks treat efficiency and equity not as opposites, but as complementary goals that must be actively balanced through careful design.

Equity demands that the benefits of well-located, productive land are accessible to all members of society — not merely those with the greatest purchasing power. Historically, land markets have concentrated wealth and opportunity among landowners while displacing lower-income residents from areas of high amenity. Equitable land policy intervenes to ensure that public infrastructure investment, zoning decisions, and development rights are distributed in ways that broaden access and reduce spatial inequality.

This approach recognizes that secure land rights are not a luxury — they are a foundation for health, economic participation, and human dignity. Planning must reflect this reality.

7. ECOLOGICAL EFFICIENCY

Across the globe, the decisions we make about land — what to grow, where to build, which ecosystems to protect — carry consequences that ripple through climate systems, food supplies, and biodiversity for generations. Chapter 1 examines the fundamental tensions at the heart of modern land use.

The 21st century has placed extraordinary pressure on the world's land resources. As the global population approaches 10 billion and consumption patterns intensify, land is being asked to serve more

masters than ever before — simultaneously feeding people, storing carbon, sheltering biodiversity, and supplying raw materials for a growing economy.

Global food demand is projected to increase by 50–70% by 2050. Agricultural expansion, intensification, and changing dietary habits — especially rising meat consumption in developing economies — are driving unprecedented pressure on agricultural and natural lands alike.

Land use change accounts for roughly 23% of total anthropogenic greenhouse gas emissions. Simultaneously, land must serve as a critical sink for carbon sequestration, making its management central to any viable climate mitigation and adaptation strategy.

Land use planning today faces what researchers describe as a **triple challenge**: meeting food security requirements for a growing population, maintaining the ecosystem services that sustain life on Earth, and reversing catastrophic biodiversity loss — all while navigating the twin imperatives of climate mitigation and adaptation. These objectives are deeply interconnected, yet frequently in direct conflict with one another. Expanding cropland boosts food supply but destroys habitat and releases stored carbon. Restoring forests sequesters carbon and supports biodiversity but reduces land available for agriculture. Current land use patterns are far from optimal for addressing any one of these challenges — let alone all three simultaneously.

For most of human history, land use decisions were shaped not by ecological rationality, but by tradition, cultural inheritance, local economic conditions, and short-term production incentives. Farmers cultivated what their parents had cultivated. Settlements grew where transportation was convenient. Grazing patterns followed centuries-old routes rather than scientific assessments of carrying capacity or biodiversity sensitivity.

Across the world, landscapes tell a story of two competing realities: the intricate, self-sustaining complexity of natural ecosystems, and the simplified, high-output monocultures engineered for maximum human yield. The challenge of ecological efficiency lies in reconciling these two worlds — finding land use configurations that honor both imperatives without sacrificing one entirely for the other.

Transforming land use from historically-driven patterns to ecologically rational allocations requires more than good intentions — it demands sophisticated scientific tools, integrated modeling frameworks, and a rigorous understanding of the complex trade-offs involved. Chapter 2 explores the cutting-edge science driving this transformation.

Modern land use optimization combines **dynamic vegetation models** — which simulate how ecosystems respond to land cover changes over time — with multi-objective optimization algorithms. The result is a set of **Pareto-optimal solutions**: allocations from which it is impossible to improve one objective without worsening another. This defines the true frontier of what is achievable.

8. EFFICIENCY ASSESSMENT CRITERIA

As global populations rise and environmental pressures intensify, how we allocate, manage, and optimize land has never been more consequential. This chapter establishes why land use efficiency sits at the heart of sustainable development.

At its core, land use efficiency is about stewardship — meeting the needs of today's populations without diminishing the capacity of future generations to meet their own. This means balancing agricultural productivity, ecological preservation, and urban development within a finite and irreplaceable resource base.

The central challenge of land use efficiency lies in reconciling two legitimate, urgent demands: expanding food production and urban development to support a growing global population, while preserving the ecological systems that make life on Earth possible. This balance is achievable — but only through intentional, science-driven policy and management.

Rigorous, evidence-based methodologies are the foundation of any meaningful land use efficiency assessment. This chapter explores the landscape of research approaches, quantitative tools, and analytical frameworks that define the field.

The dominant research lens is environmental science and ecology, accounting for **75.48%** of all reviewed studies. This reflects the field's roots in understanding ecosystem services, land degradation, and the ecological consequences of land management decisions — even as economic and social perspectives are increasingly integrated.

A comprehensive systematic review examined **208 representative papers**, oral reports, and project reports spanning multiple decades and disciplines. The body of literature reveals a rapidly growing field, with the volume of publications on land use efficiency assessment accelerating significantly in recent years — a sign of increasing urgency and scientific attention.

Over **46.63%** of all reviewed studies adopt the DEA model as their primary analytical tool. DEA is a non-parametric method that measures the *relative* efficiency of decision-making units by comparing inputs to outputs — making it ideal for benchmarking land use performance across regions, countries, or time periods without requiring a predefined production function.

DEA's strength lies in its flexibility: it can handle multiple inputs (land area, water, labor, capital) and multiple outputs (crop yield, ecosystem services, carbon storage) simultaneously. This multi-dimensional capability aligns perfectly with the complex, multi-output nature of land use systems, making it the go-to framework for researchers and policymakers alike.

Modern land use efficiency assessment draws on a rich arsenal of quantitative tools — from DEA models and stochastic frontier analysis to spatial econometrics and machine learning algorithms. The sophistication of these methods reflects the complexity of the systems they seek to understand, and the high stakes of getting the analysis right.

9. ECOLOGICAL BALANCE AND LAND USE

Our planet's land is finite — yet the pressures on it have never been greater. This presentation explores the forces reshaping Earth's landscapes, the consequences for biodiversity and climate, and the pathways toward a more sustainable future.

Across the globe, the delicate equilibrium between human activity and the natural world is under mounting stress. Land transformation, resource extraction, and expanding populations are pushing ecosystems toward irreversible tipping points. Understanding the scale of this challenge is the first step toward meaningful change.

What once took millennia now takes decades. The conversion of wild landscapes into agricultural fields, urban sprawl, and industrial zones represents one of the most profound transformations in the planet's history — and one of the most consequential.

Life on Earth is disappearing at a rate unprecedented in human history. The sixth mass extinction is not a future scenario — it is unfolding now, driven primarily by how we use, transform, and degrade land. The consequences for ecosystems, economies, and human well-being are profound and far-reaching.

From the Bengal tiger to coral reef ecosystems, the web of life is unraveling. Species that evolved over millions of years face elimination within decades — the irreversible loss of biological heritage that once lost, can never be recovered.

Land and climate are inseparable. How we manage — or mismanage — the world's landscapes directly shapes the trajectory of global warming, while a changing climate simultaneously transforms what those landscapes can support. This two-way relationship lies at the heart of the sustainability challenge.

Behind every wasted meal lies a hidden footprint: cleared forest, drained aquifer, emitted greenhouse gas. When we discard food, we discard the land and resources that produced it. Tackling food loss and waste — from farm to fork — is one of the most impactful levers available for reducing pressure on the world's land and climate systems. It requires action across production, supply chains, retail, and consumer behavior simultaneously.

10. EFFICIENCY REVIEW

As global populations surge and cities expand, the way we use land determines the quality of life for billions. This presentation explores evidence-based strategies, case studies, and technologies that can help us build smarter, greener, and more resilient communities.

Unprecedented urbanization is reshaping our planet. As cities grow faster than ever before, the decisions we make about land — where to build, how densely, and at what environmental cost — will define the sustainability of our civilization for generations to come.

Cities that expand without rational planning create landscapes defined by congestion, pollution, and lost natural capital. The visible haze over many major metropolitan areas is a tangible symbol of the hidden costs that inefficient land use imposes on residents, economies, and the planet.

Researchers examined **197 counties** across the Beijing-Tianjin-Hebei (BTH) urban agglomeration in 2018, measuring Urban Land Use Efficiency (ULUE) through a comprehensive multi-input, multi-output framework. This mega-region, home to over 110 million people, represents one of China's most critical development zones.

Modern geospatial technology has transformed how planners understand and manage land. From real-time satellite data to predictive modeling, digital tools are making it possible to design cities that are both functionally efficient and ecologically responsible.

Advanced geospatial visualization tools allow planners to see the invisible — how population density, infrastructure, green space, and economic activity interact across a landscape. Precision mapping is the foundation of rational, evidence-driven land use decisions that balance growth with sustainability.

Ports, rail yards, and distribution hubs are the arteries of the global economy. Strategic siting and zoning of freight infrastructure — informed by FELU principles — can dramatically reduce transportation costs, emissions, and community impacts while strengthening supply chain performance and regional competitiveness.

11. CONCLUSIONS

Land use is a dynamic and essential aspect of human interaction with the environment. Different forms of land use serve various economic and social needs, but they also have significant environmental impacts. Unsustainable practices can lead to land degradation, pollution, and ecological imbalance.

Effective land use planning and management are necessary to ensure that land resources are used responsibly. By adopting sustainable land use practices, societies can achieve a balance between development and environmental conservation, ensuring the well-being of current and future generations.

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