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Exploration of Sustainable Development Pathways for Rural Revitalization in Arid Regions: An Empirical Study of Xinjiang Based on Human Settlements Science

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Abstract. Rural revitalization in arid regions faces complex challenges encompassing ecological fragility, resource constraints, and industrial homogeneity. This paper adopts the framework of Human Settlements Science, grounded in the natural ecological characteristics and multicultural context of rural areas in Xinjiang's arid regions, to systematically diagnose the underlying causes of their developmental dilemmas. The study argues that breaking the vicious cycle of "ecological fragility—economic lag—industrial homogeneity" is a critical prerequisite for rural revitalization in arid regions. To this end, the paper proposes a systematic strategic framework of "protection—adaptation—empowerment—collaboration", driven by ecological restoration, optimization of water and land resources, cultivation of regional specialty industries, and digital technology empowerment. This framework addresses four dimensions: natural system restoration, adaptive renewal of settlement spaces, establishment of specialized industrial systems, and digital collaborative governance, aiming to explore sustainable development pathways for rural areas in arid regions that balance ecological security, economic vitality, and social resilience

Keywords: Arid regions, Living environments, Fragile ecosystems, Sustainable development, Xinjiang

Introduction

Xinjiang is located in the northwest of China, covering a total area of approximately 1.6649 million square kilometers, accounting for one-sixth of the country's land area, making it the largest provincial-level administrative region in China by area. Arid zones constitute about 43% of the region, including 420,000 square kilometers of desert and 290,000 square kilometers of Gobi Desert. The extremely arid zone (with annual precipitation <200 mm) dominates areas such as the Tarim Basin, Junggar Basin, and Turpan Basin. As a vital ecological barrier and strategic stronghold in northwestern China, the sustainable development of Xinjiang's rural areas not only concerns regional stability and public welfare but also serves as a critical implementation site where China's two major strategies—"Rural Revitalization" and "Ecological Civilization Construction"—intersect in this unique frontier region.

The Rural Revitalization Strategy, serving as the overarching approach for China's "agriculture, rural areas, and farmers" work in the new era, is a crucial pathway to addressing issues of unbalanced and inadequate development and achieving common prosperity [1]. As a national strategy, its theoretical framework and implementation approach are grounded in the natural and cultural systems of specific regions, closely aligned with their respective developmental stages.

The region generally faces a contradiction between the national strategic requirement for high-quality development and its fragile local ecology. On one hand, the national strategy demands thriving industries, an eco-friendly living environment, and prosperous livelihoods; on the other hand, natural conditions such as drought, water scarcity, ecological fragility, and limited resource and environmental carrying capacity constrain economic development. The traditional extensive development model is no longer sustainable and may even exacerbate the vicious cycle of ecological degradation and poverty. To resolve this contradiction, it is necessary to establish a theoretical framework and practical approach that systematically balances nature conservation, economic development, and social progress.

In 1993, Wu Liangyong first proposed the concept of "Human Settlement Environment Science", developing a systematic theory that emphasizes studying the objective principles governing human living environments from an integrated and interdisciplinary perspective. This groundbreaking theory establishes a research framework for rural human settlement environments, comprising five subsystems: natural, human, social, residential, and supporting [2]. Conduct a comprehensive and integrated study of rural society.

This study adopts a systematic perspective from the field of human settlement science. By identifying the root causes of systemic imbalances, it clarifies the core principles for revitalization and proposes a tiered, actionable strategy framework. The aim is to provide theoretical references and practical guidance for sustainable development in such regions, while exploring a sustainable path that integrates ecological safety, spatial adaptability, cultural continuity, and economic viability.

The methodology

Water resources are a critical component of natural systems. The annual average precipitation in Xinjiang is significantly lower than the evaporation rate, leading to intense competition for agricultural, ecological, and domestic water use. This is accompanied by risks of land desertification and salinization. The area of desertified land in Xinjiang amounts to 746,800 km², accounting for 44.86% of the region's total land area [3] (Figure 1). Xinjiang is also the region with the most extensive distribution of saline-alkali land in China, where the area of salinized soil accounts for approximately 30% of the national total [4] (Figure 2). The ecosystem exhibits poor

stability and weak self-repair capacity. Coupled with harsh climatic conditions such as wind-blown sand, intense sunlight, and significant temperature fluctuations, it constitutes an ecosystem with low carrying capacity and high sensitivity. Inappropriate human interventions can readily trigger ecological degradation, lead to environmental pollution, and create a vicious cycle of “resource constraints → development limitations → ecological deterioration”, resulting in frequent occurrences of poverty.



Figure 1– Land Desertification. Image source: Internet.



Figure 2– Land salinization and alkalinization. Image source: Internet.

The Diversity and Lagging Nature of Human and Social Systems

Under the harsh constraints of nature, the human and social systems of Xinjiang are unique and complex. Since Zhang Qian's mission to the Western Regions during the Han Dynasty, the Central Plains dynasties governed the region by implementing military strategies such as garrison farming and border defense. Diverse ethnic cultures interacted, exchanged, and integrated here, giving rise to rich livelihood patterns, living customs, social norms, and spatial perceptions. The coexistence of these diverse ethnic cultures has generated differentiated needs and corresponding governance challenges.

At the economic level, rural areas in Xinjiang currently face challenges such as insufficient growth momentum, severe homogenization of development models, and inadequate development of characteristic industries [5]. Although adjustments and optimizations have been made to the industrial structure, the agricultural foundation remains weak, still dominated by low-level crop farming and animal husbandry. The primary agricultural products consist mainly of raw commodities such as cotton and fruit trees, with low added value [6]. The agricultural and livestock sectors are still in the transition phase from traditional to modern practices [7]. The intertwined challenges of a homogeneous traditional industrial structure and a lack of endogenous growth drivers have resulted in sluggish regional economic growth, coupled with insufficient resilience against external market fluctuations and natural risk shocks. The outflow of young and middle-aged laborers has led to a pronounced phenomenon of rural hollowing-out [8]. Under the impact of modernization, the self-organizing capacity of rural areas also faces an urgent need for restructuring and enhancement.

Incompatibility between the residential system and the supporting system

As the physical foundation for housing and support systems, these structures fail to meet the actual spatial demands of daily life and production during the transition between traditional and modern lifestyles. Villages in arid regions generally adhere to the principle of “settling near water sources” when selecting their locations [9]. However, under the impact of modern production and lifestyle patterns, issues such as fragmented land use, mixed functions, or partial regional decline have emerged; Traditional rammed-earth buildings that embody climate adaptation wisdom, such as Aiywang and yurt-style structures, have gradually been phased out due to their inadequate comfort and incompatibility with modern living habits.

The construction of farmland irrigation facilities has progressed slowly, with some irrigation equipment being outdated and water resource utilization efficiency being low, failing to meet the demands of high-efficiency agriculture [10]; The deployment density of new information infrastructure such as 5G base stations is significantly lower than the national average. In some remote villages of Xinjiang, communication networks have not achieved full coverage, leaving rural and pastoral areas facing the “last mile” access challenge [11], making it difficult to meet the demands of sustainable economic development.

Analysis of the interaction mechanisms between systems

The scarcity of water resources and weak self-repair capabilities in natural systems directly constrain the stability of rural industrial development, resulting in low economic output with significant volatility. To sustain their livelihoods, farmers often engage in short-term practices such as excessive land cultivation and overgrazing, further exacerbating land degradation and water resource depletion. Limited incomes prevent them from investing in water-saving technologies or ecological conservation, hindering economic growth. The lack of economic opportunities leads to the outflow of young and able-bodied labor, causing rural “hollowing out”. This not only undermines rural vitality and development momentum but also hinders the organization of effective collective actions to drive industrial upgrading, thereby perpetuating the state of economic backwardness.

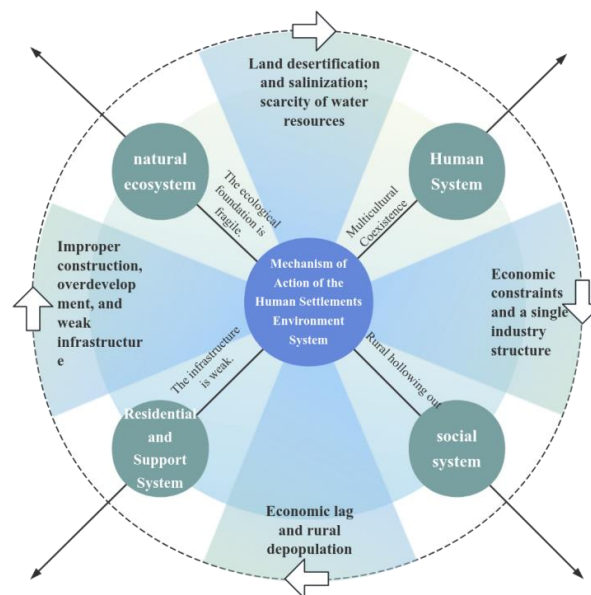


Figure3. Schematic diagram of the circular system for rural living environment in Xinjiang. Drawn by the author.

Inadequate spatial planning and weak infrastructure exacerbate resource consumption, hinder the upgrading of specialized industries, and lead to excessive exploitation of natural resources and improper development practices, which in turn suppress economic growth and population return. From the perspective of the Human Settlements System Theory, the failure to establish positive synergies among systems results in a complex vicious cycle (Figure 3), creating a self-reinforcing negative feedback loop.

The principles of rural revitalization derived from the human settlement system

Revitalization Principle

The complex and interwoven characteristics and challenges of rural areas in the Xinjiang arid region often render fragmented, one-dimensional response strategies largely ineffective, and may even give rise to new systemic issues. Within the specific geographical context of Xinjiang, the relationships among the five major systems—natural, human, social, residential, and support systems—exhibit distinct hierarchical and constraining patterns, leading to the formulation of four core revitalization principles as illustrated in Table 1.

Table 1. The Four Major Revitalization Principles

Ecological Conservation	Regional Adaptation	Cultural Empowerment	System Synergy
1. Determine urban planning, land use, population distribution, and industrial development based on water resources.	1. Smart Response to Natural Ecosystems	1. The Living Transmission and Innovative Expression of National Culture	1. Digital empowerment of rural governance
2. Strictly adhere to the ecological protection red line	2. Advocating adaptive design	2. Avoid homogenization	2. Accurate implementation of resource allocation
3. Protection of key ecological elements	3. Uncover the wisdom of traditional ecology	3. Enhance a sense of identity, product appeal, and added value	3. Enhanced System Forward Cycle
Overall Goal: Enhance the operational efficiency of rural living systems			

Ecological Protection

Consider ecosystem integrity as a critical constraint for land development [12]. Water resources are vital national assets that underpin urban development and economic growth, yet they also represent the most significant constraint. The principles of “planning cities, allocating land, determining population size, and regulating industries based on water availability” constitute fundamental planning guidelines [13]. In practical production and daily life activities, strict controls must be implemented to prevent damage to spatial boundaries such as ecological protection red lines and permanent basic farmland, with priority given to the protection and restoration of critical ecosystems including oases, rivers, and wetlands.

The traditional development model, oriented toward economic growth and spatial expansion, must be grounded in the fundamental principles of ecological security and sustainable resource utilization. Planning and construction activities should establish a mandatory ecological impact

assessment mechanism to ensure that developmental activities remain within the ecological carrying capacity threshold.

Regional Adaptation

Residential and supporting systems must adhere to the core principle of “regional adaptation” to address ecosystem vulnerabilities. Regional design emphasizes adaptability to the natural environment; planning should not deviate from local natural conditions but rather utilize and protect these resources in a context-specific manner while respecting nature, thereby achieving harmonious coexistence between humans and nature [14]. It is essential to thoroughly explore and scientifically translate the construction wisdom accumulated by local residents through their long-term adaptation to drought, sandstorms, and temperature variations.

Cultural Empowerment

The principle of “cultural empowerment”, which centers on human and social systems as its core values, seeks to integrate regional characteristics into the dynamic inheritance and innovative expression of multi-ethnic cultures. By leveraging Xinjiang’s rich historical and cultural heritage, it aims to prevent severe homogenization. This approach respects, protects, and creatively transforms the historical memories, modes of production and lifestyle, and aesthetic concepts of various ethnic groups, enabling traditional culture to rejuvenate in contemporary life. Consequently, it enhances residents’ sense of identity, increases product appeal, and elevates industrial added value.

System Synergy

By applying the principle of digital system collaboration, digital technologies empower rural governance, enabling precise allocation of resources and services, targeted policy implementation, and refined management control. This approach overcomes spatial barriers and resource management challenges with greater precision and efficiency. It strengthens positive interconnections and feedback loops between systems, breaks the vicious cycle, enhances overall efficiency, and improves the operational effectiveness and resilience of the entire rural living system.

Sustainable Pathways for Rural Revitalization in Xinjiang

Guided by the four principles of “ecological protection, spatial adaptation, cultural empowerment, and systemic synergy,” an integrated implementation framework encompassing protection, adaptation, empowerment, and synergy was established (Figure 4). Aiming to break the vicious cycle of “ecological degradation–economic poverty–social stagnation–improper development – systemic imbalance – ecological deterioration”, the framework comprises a mutually interconnected and progressively layered strategy system across four dimensions: natural system restoration, adaptation of residential support systems, activation of human social systems, and integration of technological synergy systems.

Regional Ecological Restoration and the Safety Bottom Line

National land ecological restoration is a systematic project [15]. It requires a comprehensive spatial intervention framework spanning from macro-level baseline management to micro-level ecological enhancement. The goal is not only to curb ecological degradation but also to create a more resilient, safe, and healthy ecosystem capable of continuously providing ecological products and services—thereby ensuring the sound development of other human settlement systems and achieving “ecological restoration and green development.”

Conduct systematic planning based on natural geographical units such as river basins and oases. Scientifically identify, strictly delineate, and rigorously adhere to ecological protection red lines, incorporating key ecological function zones and sensitive, vulnerable areas into mandatory

protection zones. Embrace the systemic concept that “mountains, rivers, forests, farmlands, lakes, grasslands, and deserts form an integrated community of life.” Considering the diversity of ecological types in border regions, establish three control lines: ecological protection red lines, environmental quality baselines, and resource utilization ceilings. Implement key ecological projects in border regions to advance integrated ecological protection and systematic governance [16]. Establish a structurally complete and functionally stable regional ecological security network, setting a baseline for rural development.

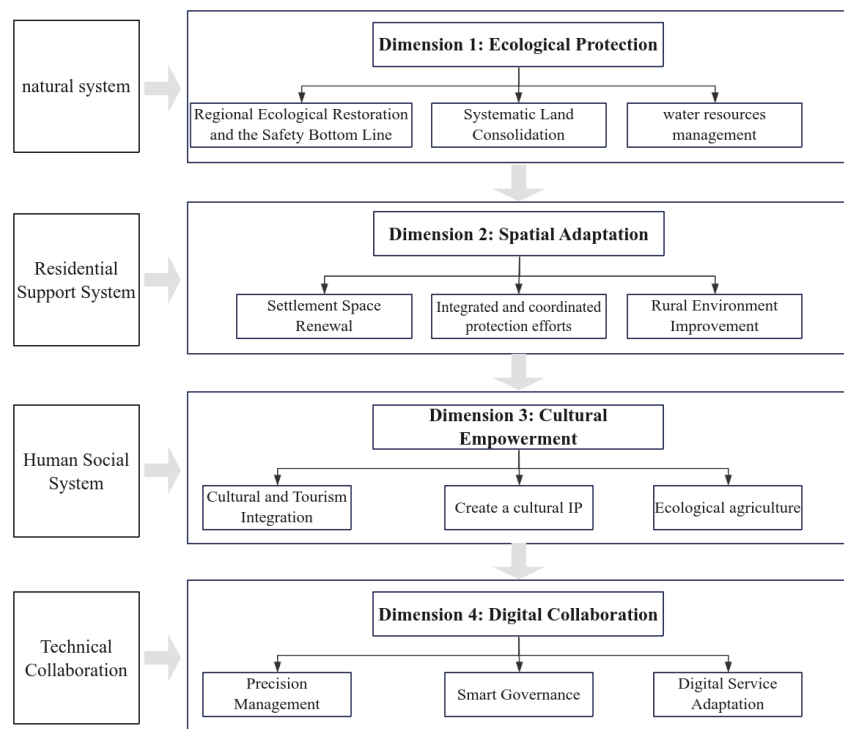


Figure 4. Schematic diagram of sustainable practice pathways. Drawn by the author.

Results and Discussion

Systematic Land Consolidation and Water Resource Management

Systematic Land Consolidation

Conduct comprehensive land consolidation across the entire territory to optimize and adjust the spatial layout of production, living, and ecological areas, achieving efficient land use and enhanced ecological functions. Establish water resource carrying capacity as the core parameter in spatial planning to determine the appropriate scale and distribution of population, industries, and construction land, guiding settlements to concentrate in areas with relatively superior water resources or high-water efficiency.

We will advance ecological land remediation by systematically restoring and adapting mechanization to fragmented farmland, saline-affected areas, and marginal abandoned farmland resulting from over-development. Employing a community-based participatory approach under integrated ecosystem management, we will intensify efforts to mitigate degradation in saline-affected land restoration, desertification control, land rehabilitation, ecological conservation, and

afforestation, thereby achieving optimal overall ecological balance [17]. Concurrently, we will establish farmland shelter-belt networks to improve micro-climates (Figure 5), promote ecological space integration through village consolidation and construction land reclamation, gradually phase out human activities in ecologically sensitive zones, and connect fragmented forest and grassland patches into a cohesive green infrastructure network that encircles or interconnects rural areas.



Figure 5. Systematic land consolidation. Image source: Internet.

Water Resources Management

At the basin level, establish and strictly adhere to the upper limits for water resource development and utilization, then break them down progressively to prefectures, counties, cities, and even townships, thereby forming a comprehensive total water use control indicator system covering the entire society. The approach should shift from simply determining water supply based on demand to a strategy of balancing water supply and demand grounded in enhanced demand management [18]. Priority should be given to safeguarding river ecosystems and ensuring drinking water safety for urban and rural residents; on this basis, agricultural and industrial water quotas should be dynamically optimized according to each prefecture's primary functional positioning, resource endowment, and efficiency levels.

Promote water-saving agricultural practices such as drip irrigation and sprinkler irrigation to enhance agricultural water utilization efficiency [19]. Concurrently, implement modernization upgrades to farmland water conservancy projects. Establish a corresponding precision water management system—including smart metering, quota management, and water rights trading—to ensure that water-saving technologies translate into actual water conservation, preventing the “water-saving effect” from being offset by expanded irrigation areas.

Leveraging modern information technology, we enhance the precision, intelligence, and coordination of water resource management. By integrating multi-source data from meteorology, hydrology, agriculture, and municipal sectors, we establish digital twin river basins and smart water networks to achieve comprehensive intelligent monitoring, forecasting, early warning, optimized scheduling, and emergency management across the entire water supply chain from source to end-user. A transparent platform for water rights confirmation, registration, and trading is established to facilitate inter-regional, inter-industry, and inter-user water rights transactions. Through mobile applications and other channels, water condition information is made public, water conservation services are provided, and public participation and oversight channels are

expanded, fostering a collaborative water governance framework involving the government, market, and society.

Adaptive Renovation of Settlement Spaces

The adaptive renewal of settlements must address the current inefficiencies in residential and support systems and their incompatibility with modern production and lifestyle practices. Through rational planning and design, the natural environmental foundation and regional cultural characteristics should be transformed into efficient spatial configurations and rural landscapes, shifting from passive adaptation to active integration with the environment to achieve harmonious coexistence between humans and nature. A resilient residential and support system that responds to climate change, conserves resources, and preserves cultural continuity should be proactively established.

Coordinated and Contiguous Layout of Rural Spaces

The village has transitioned from a traditional layout pattern constrained by water resources to an intensive model based on modern, efficient water resource allocation and ecological security. Guided by the principle of “land use determined by water availability,” this transformation integrates comprehensive land consolidation, defines village construction boundaries, and restricts the uncontrolled expansion of residential activities within ecologically sensitive zones. Population and development activities are directed toward central villages or communities with well-developed infrastructure and relatively superior water resources, forming integrated clusters with mixed functions and shared services to achieve coordinated, contiguous conservation.

The village’s spatial structure has been optimized by drawing on the wisdom of traditional settlements in mitigating wind, sand, and sunlight exposure. A clustered, enclosed layout has been adopted, where building clusters provide mutual shading, creating an effective microclimate zone that protects against wind and sand. The streets and alleys between buildings also account for the prevailing summer wind direction to enhance ventilation while avoiding winter wind directions, ensuring a comfortable living environment for residents.

Rural Environment Improvement

Waste management constitutes a fundamental project for rural environmental improvement, aimed at enhancing village aesthetics, ensuring ecological security, and elevating public health standards. Establishing a waste transfer system tailored to regional characteristics represents a systematic endeavor that integrates spatial adaptability, technological suitability, economic feasibility, and coordinated management, thereby controlling domestic pollution at its source and preventing secondary damage to soil and water bodies.

Following the “household sorting–village collection–township transfer–county processing” model [20], a scientific and efficient waste collection and transportation system will be established. Pilot programs will implement source sorting and reduction of recyclable and organic waste to achieve resource recovery. Transfer stations will be designed to meet the temporary storage and compression transfer needs of their service areas. In arid regions, low-cost, low-maintenance sun composting technology will be actively explored for organic waste treatment; in areas with high fuel costs, low-temperature pyrolysis or carbonization technologies suitable for small-scale waste can be piloted to achieve both waste reduction and resource recovery. Currently, the Xinjiang region has implemented various efficient waste disposal methods (Table 2).

By adopting the sponge village concept to harness natural drainage forces and employing Low Impact Development (LID) technologies for decentralized treatment of non-point source wastewater at its source, water quality is purified [21]. Ecological restoration techniques are

integrated into rural development to enhance ecological resilience, with efforts to establish rainwater management and microclimate regulation systems. Leveraging topographic elevation differences, facilities such as ecological ditches, infiltration ponds, and reservoirs are designed to collect and store rainwater and snowmelt for landscaping and sanitation purposes. Additionally, drought-resistant plants are used for village greening, while some roads are replaced with permeable surfaces instead of hard pavements.

Table 2. Xinjiang's efficient waste disposal model

Governance Model	Core Ideology	Representative Case	Key Achievements
Reduction through source-based classification	"The trash doesn't leave the village."	Ruoqiang County (Intelligent Recycling)	The wastewater resource utilization rate in Ruoqiang County has reached 80%.
Technology-Driven Processing	Applications of "Low-Temperature Magnetization"	Baojiadian Village, Manas County (Enterprise Operation)	Process 200 tons of waste to produce 1 ton of magnetized ash suitable for landscaping applications.
Professional Centralized Processing	A three-level coordination mechanism involving "Household, Village, and City"	Jiujianlou Township, Wusu City, Tacheng Region (Integrated Urban and Rural Sanitation System)	With a daily processing capacity of 10 tons, it effectively addresses waste collection challenges.
Institutional innovation activates progress.	"Small Points" Drive Comprehensive Governance	Er Gong Town, Jimusaer County; Jinhua New Village, Wensu County; Awati County (point redemption)	Dashi Tou Township generates an annual revenue of one million yuan through services provided to surrounding areas.
Cycling of Agricultural Resources	"Turning Waste into Gold"	The 6th Division of the Corps and the 12th Regiment of Southern Xinjiang (drip irrigation tapes, residual film recovery)	The 9th Division converts hundreds of tons of livestock manure into high-quality organic fertilizer, while processing residual plastic films into recycled plastic pellets.

Cultivation of Regional Characteristic Industries

Scientifically cultivate leading industries

At the 2026 China Two Sessions, the government work report proposed "promoting high-quality development of the cultural and tourism industry and enriching integrated sectors such as culture, tourism, sports, and commerce," providing crucial policy guidance and strategic

opportunities for rural development in the arid regions of Xinjiang. It is essential to establish a vibrant, sustainable, and inclusive endogenous economic system to address long-standing challenges including a single industrial structure, low added value, and insufficient endogenous momentum. This involves transforming ecological constraints into quality advantages and converting cultural resources into core product strengths.

Based on a profound understanding and scientific assessment of regional resources, the industrial system is established in accordance with the dual principles of “ecological suitability” and “cultural uniqueness”, strictly adhering to water resource red lines and ecological carrying capacities, with a focus on developing distinctive ecological agriculture characterized by high water productivity, high added value, and environmental sustainability.

Xinjiang proposed the overall agricultural development strategy of “stabilizing grain production, adjusting cotton cultivation, optimizing fruit cultivation, and promoting animal husbandry” [22]. By adjusting the path of industrial upgrading, expanding the planting areas of coarse grains, specialty crops, and forage grasses, strengthening the regional specialization advantages of cotton and specialty forestry and fruit industries, and advancing the development of agricultural functional zones and advantageous production areas.

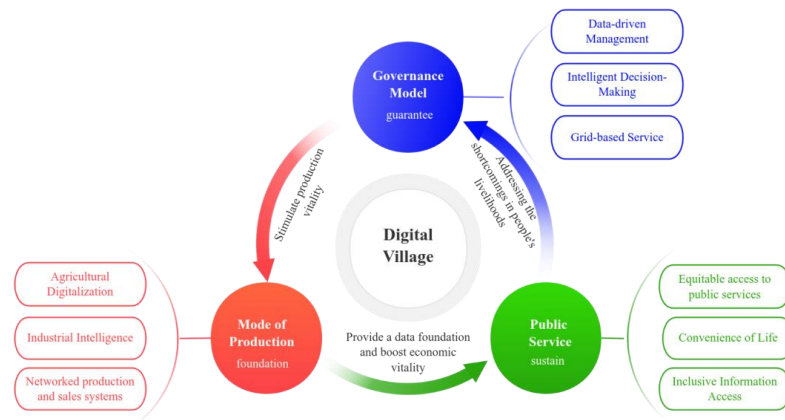


Figure 6. Digital Village Analysis Map. Drawn by the author.

Digital technology enables system collaboration

Building a new type of digital countryside represents an innovative model for social management under current circumstances. By fully leveraging the integrated application of next-generation information technologies such as the Internet of Things, cloud computing, and the internet, we aim to create a digital countryside that integrates security, management, services, and cultural elements. Essentially, this involves the deep integration of digital technologies into rural socio-economic systems, driving systemic transformations in governance models, production methods, and public service frameworks. This process follows an evolutionary trajectory from data resource utilization to intelligent resource management (Figure 6).

Confronted with inherent challenges such as vast geographical expanses, dispersed resources, extensive management coverage, and information asymmetry, traditional rural governance approaches have proven inadequate. As a core element of new-quality productive forces, digital technology offers systematic and precise solutions by deeply integrating it into all subsystems of the rural living environment. This enhances governance accuracy, service efficiency, and

development resilience, facilitating the transition from traditional management to modern “smart governance.”

For instance, promote the application of data in planning and management by leveraging the GIS platform to centrally manage ecological protection red lines, village planning, construction projects, and industrial layouts, enabling precise spatial control and dynamic assessment. The planning framework incorporates promptly updated land use status data, ownership information, and a comprehensive GIS “single map” management system [23].

In cultural and tourism development, real-time monitoring of visitor flow density at scenic spots can be achieved by integrating data from surveillance cameras and mobile signaling systems, enabling dynamic crowd management to prevent ecological overload and safety incidents, thereby realizing “smart visitor flow management.” Regarding technological tool development, “age-friendly” applications incorporating voice interaction, video guidance, and large-font displays should be promoted to lower usage barriers. In multi-ethnic regions, the provision of bilingual digital content and interface design must be enhanced to ensure cultural compatibility of digital services. By integrating digital skills training with industries requiring digitalization—such as e-commerce operations and tourism services—villagers can transition from mere “spectators” to active “participants” and “beneficiaries” of the digital era.

Conclusion

This study adopts the framework of Human Settlements Science to systematically examine the practical challenges and potential solutions for sustainable rural development in the arid regions of Xinjiang. The research reveals that the core obstacle to rural revitalization in these arid areas lies in the “structural imbalance” among five subsystems—natural, human, social, residential, and supportive—and the resulting complex vicious cycle. To address this challenge, the paper proposes a revitalization approach guided by the principles of “ecological protection, regional adaptation, cultural empowerment, and systemic synergy,” and establishes an integrated implementation strategy encompassing protection, adaptation, empowerment, and collaboration.

First, based on regional ecological restoration and the bottom-line management of water and soil resources, establish a solid natural foundation for rural development in arid areas by delineating ecological red lines, advancing comprehensive land consolidation across the region, and implementing refined water resource management in river basins. Second, leverage adaptive renewal of settlement spaces, promote integrated and contiguous village protection alongside the deployment of modern green infrastructure to create resilient living environments adapted to arid climates. Third, driven by the development of regional characteristic industries, transform multicultural ethnic resources and ecological conditions into distinctive industrial IP, fostering an inclusive and mutually beneficial endogenous economic system. Fourth, supported by digital technology-enabled system collaboration, establish a smart governance platform to overcome geographical barriers and information asymmetry, ensuring precise implementation and dynamic adjustment of various strategies.

The aforementioned strategic framework aims to break the vicious cycle of “ecological degradation—economic stagnation—social weakening” in rural areas of arid regions, exploring a sustainable revitalization path that balances ecological security, cultural continuity, economic viability, and efficient governance. It also serves as a valuable reference for rural development in other ecologically fragile areas.

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The contribution of the authors

Saierjiang·Halike – concept, methodology, resources, data collection, testing, visualization, interpretation, drafting, editing, funding acquisition.

Wei Tangzhi – data collection, testing, visualization.

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