Zoning and Optimization Strategies of Land Spatial Ecological Restoration in Liangjiang New Area of Chongqing Based on the Supply–Demand Relationship of Ecosystem Services

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Abstract: Ecological land restoration is necessary to develop a comprehensive land amalgamation strategy. Scientific ecological restoration zoning is crucial for the development of differentiated restoration strategies, as well as for the improvement of quality during construction. This study used a series of methods, such as the InVEST model, spatial autocorrelation, and coupling coordination degree models, using Liangjiang New Area as an example to quantify both regional ecosystem services supply and demand at the county and district levels. The land’s spatial ecological restoration zones were determined, and the optimization strategies based on the supply–demand matching and coordination relationship were presented. The results revealed the following: (1) A considerable difference was identified between the supply and demand of ecosystem services in Liangjiang New Area of Chongqing, with “high in the northeast and low in the southwest” spatial patterns for supply and “high in the southwest and low in the northeast” spatial patterns for demand; (2) The supply–demand matching relationship of ecosystem services in Liangjiang New Area of Chongqing was characterized by spatial mismatches of high supply and low demand and low supply and high demand, with an average coordination degree index of 0.2, indicating uncoordinated supply and demand; (3) Based on the supply–demand relationship of ecosystem services, the regional ecological base, and the functional orientation of upper planning, Liangjiang New Area was divided into four zones: high supply–low demand, low supply–high demand, and high supply–high demand zones, for which the respective optimization strategies were presented. In some ways, this study contributes to the existing research concerning the supply–demand relationship for small-scale ecosystem services in new development zones located in mountainous cities.

Keywords: ecosystem services; supply–demand relationship; land ecological restoration; spatial zoning; optimization strategies; Liangjiang New Area

1. Introduction

Since the reform and opening up of China, industrialization and urbanization have advanced, leading to intensified development and construction and unreasonable use of land resources [1]. This has caused disordered development of land space and the deterioration of the ecological environment, a scenario that has affected the socio-economic sustainability and sustainable use of natural resources to a certain extent [2]. Since the 18th National Congress of the Communist Party of China, at which coordinated management of mountains, waters, forests, farmland, lakes, and grassland was proposed, the conservation of the ecological systems has been included in the Five-Sphere Integrated Plan and the Four-Pronged Comprehensive Strategy [3]. Subsequently, the most stringent ecological environment protection system has been implemented. The importance of land spatial ecological restoration has been highlighted in recent years for sustainable development,
To safeguard regional ecological security and to improve ecosystem service functions, zoning of land spatial ecological restoration refers to zoning research and governance of land ecological restoration, depending on the terrain, climate, vegetation, soil, and other elements in different regions. It can optimize land-use efficiency and quality, resource utilization efficiency, and ecological environment quality. The supply–demand relationship between ecosystem services is the result of the interaction between human activities, urban development, and ecosystem services. The “structure–pattern–process–function–service (human benefit)” interconnection theory of ecosystems provides a theoretical basis and support for land spatial ecological restoration. Land spatial ecological restoration is a crucial way to improve ecosystem services. One of the significant ecological restoration goals is to enhance ecosystem services as a part of the ecological restoration process. Therefore, with the progress of land spatial ecological restoration and the in-depth study of ecosystem services, more researchers have explored land spatial ecological restoration and zoning governance from the perspective of ecosystem services. Numerous studies have been conducted on the supply and demand of ecosystem services, encompassing a broad spectrum of service types, perspectives, and approaches. Kroll et al. performed an analysis of the supply and demand characteristics of energy supply, food supply, and water supply services in the Leizig–Halle area of eastern Germany. They examined the spatial distribution patterns of these services along an urban–rural gradient, taking into account factors such as land use, soil, climate, population, and food production data. The study introduced a quantitative calculation and spatial visualization method. Their findings revealed that from 1990 to 2007, the food and water supply/demand ratios increased, while the energy supply/demand ratio decreased. These changes reflected the traditional urban and rural transformation patterns. The results hold significant implications for managers involved in coordinating sustainable regional balance. Burkhard et al. employed the central German region as a case study from 1990 to 2007. They focused on assessing the ecological integrity of biophysical landscape units and examining the matrix coupling between the supply and demand of ecosystem services. They utilized land cover data, socio-economic data, assessment methods, and assignment techniques, in combination with the previous literature, to integrate ecosystem service supply and demand values into a unified unit for quantitative analysis and to quantify variations across different land types. Serena et al. demonstrated a spatial mismatch between the supply and demand of ecosystem services. To address this issue, they developed a framework for the flow of ecosystem services and expressed the spatial relationship between supply and demand areas in terms of three services: pollination, water supply, and climate regulation. Igone et al. quantified the temporal variability of ecosystem services in Spain, particularly the Basque Country and the Bay of Biscay region. Their objective was to identify strategies for achieving a balance between local ecosystem service supply and demand, ultimately leading to sustainable land-use practices. Schulp et al. used a high-resolution land-use change model based on a GIS platform to assess land-use change trajectories and simulate land-use change across 27 EU member states to measure the connections between land-use changes and ecosystem services in EU countries and provide a scientific foundation and metrics for policy development. The research findings indicated a significant association between the reduction in land use and the provision of ecosystem services. Castro conducted a quantitative study to examine the trade-offs of ecosystem services from two aspects, namely supply and social demand, and in three dimensions, namely biophysical, sociocultural, and economic. The findings hold significant implications for analyzing the spatial dislocation of ecosystem services across different value dimensions, aiding decision makers in identifying areas with ecosystem service degradation and ecological protection priority, as well as monitoring potential contradictions that may arise during the implementation process. Drawing on the survey experiences of American community members’ perceptions of forest ecosystems, Gerald recognized and explored key issues.
Barbier expanded ecosystem service research to estuaries and coastal zones, specifically focusing on assessing the value of marine ecosystem services, which provide a scientific basis for formulating marine ecological resource restoration [19]. From a social-ecological perspective, McPhearson employed carbon sequestration, runoff regulation, food supply, and biodiversity to accomplish the ecological zoning of New York City [20]. In addition, Chinese scholars have made significant contributions to research across multiple scales, ranging from global to regional, urban, single ecosystem, and individual species domains. Xie calculated and analyzed the supply and demand of ecosystem services in the counties and cities of Guangxi at the provincial level in China [21]. Based on the special geographical conditions of Guangxi and the results of the calculation of ecosystem services, 10 restoration zones have been identified in Guangxi. The differences in rectification measures between these zones have been proposed. Based on the framework “degradation pressure–supply status–restoration potential” at the municipal level, Dan guided the zoning of land spatial ecological restoration in the Pearl River Delta by calculating the indicators of pressure, supply, and potential of the ecosystem services in the Pearl River Delta [22]. Yue quantified the supply (water yield, carbon storage, soil conservation, habitat quality) and demand (population density, level of economic development) of regional ecosystem services at the township scale and divided Guyuan City in China into six ecological zones for targeted ecological restoration [23]. Gao investigated the supply–demand spatial distribution of ecosystem services on the upper reaches of the Sanggan River (located in a zone of agriculture and animal husbandry interlocked with each other), as well as the degree to which supply and demand are matched and coordinated [8]. Five ecological restoration zones were established on the upper reaches of the Sanggan River to improve ecological functions in each zone [4]. Overall, the research on ecosystem services and its national spatial partitioning for ecological rehabilitation has made substantial contributions to the theoretical advancements in geography, ecology, and other related disciplines. It has facilitated the transition from theoretical exploration to practical application, thereby accelerating national spatial ecological restoration and ecosystem service management. However, most of the existing studies primarily focus on identifying land for ecological restoration by analyzing the supply–demand relationship of ecosystem services in the large-scale studies of economically developed coastal urban agglomerations [24], karst landforms [25], and major inland ecological areas [26]. Indeed, the current research on minor scales, specifically new urban development areas, is still lacking. Moreover, there is a noticeable gap between ecosystem services and urban management practice. Ecology and geography primarily delve into the scientific principles of ecosystem services in terms of ecosystem structure and function. In contrast, the management and sociology fields explore the ‘human–Earth relationship’ and its management practices by considering demographic, economic, and social perspectives. To effectively implement ecosystem services for enhancing human well-being and fostering sustainable regional development, it is necessary to integrate various disciplines due to their distinct positioning and focus.

In this paper, the ecosystem and economic systems of Liangjiang New Area of Chongqing are coupled, and data on water yield services, per capita GDP, and land use are integrated. Using the InVEST model [19] and GIS, the objectives were to compute and predict the supply and demand of ecosystem services, the supply–demand matching relationship, and the supply–demand coordination connection in Liangjiang New Area. Specifically, the study aimed (1) to analyze the supply–demand pattern characteristics of ecosystem services in Liangjiang New Area; (2) to study the trade-off and spatial matching relationship of ecosystem services in Liangjiang New Area; and (3) to define the land spatial ecological restoration zones as a unit of streets and propose the corresponding optimization strategies to facilitate the practice of regional ecological protection and restoration [27]. Quantifying the supply of ecosystem services in new urban development areas is essential for the development of effective management plans that ensure the sustainable and rational use of natural resources to meet human needs. By identifying the spatial distribution and
structure of the demand for ecosystem services in new urban development areas, we gain insights into the intricate relationship between ecosystem services and socio-economic development. Furthermore, exploring the dynamic interplay between the supply and demand of ecosystem services and assessing the spatial mismatch between them enables us to understand the allocation of resources within new urban development areas. This analysis helps decision makers identify potential areas of tension and risk, where there may be a disparity between the availability of ecosystem services and the demands placed on them. By identifying these areas under potential tension, decision makers can prioritize attention and allocate resources accordingly. This knowledge aids in optimizing land-use patterns and making informed ecosystem service management decisions during the planning process.

2. Study Area and Method

2.1. Study Area

Chongqing’s Liangjiang New Area, located at the intersection of the “Belt and Road” and the Yangtze River Economic Belt, is the country’s first national inland development area. The quality and efficiency of development in Liangjiang New Area have improved due to the two major orientations of building the inland open gateway and the Intelligence City of Chongqing, as well as the target of “creating the high-quality development leading area and high-quality life demonstration area” [28]. Since its establishment, the government of Liangjiang New Area has remained focused on ecological civilization system reform. It has also been actively exploring a new path of high-quality development oriented to ecological priority and green development to build an essential ecological barrier in the upper reaches of the Yangtze River, thus achieving excellent results in ecological restoration [29]. The eco-city in Yuelai was selected as one of the first eight national green ecological demonstration urban areas in 2013 [30] and one of the first sixteen sponge city pilot projects in China in 2015. “The year of park construction” was initiated in Liangjiang New Area in 2016. In 2018, the Action Plan for Implementing Ecologically Prioritized and Green Development in Liangjiang New Area (2018–2020) was officially released. In 2019, Chongqing issued a plan for the protection and improvement of “Two Rivers and Four Shorelines” (“Two Rivers” refers to the Jialing River and Yangtze River; “Four Shorelines” refers to the shoreline of Yangtze River and Jialing River flowing along the central city of Chongqing) and “Four Mountains” (Jinyun Mountain, Zhongliang Mountain, Tongluo Mountain, and Mingyue Mountain) [31]. Under the guidance of the “Urban Green Lungs, Citizens’ Garden” vision, relevant departments and district governments, including the management committees, have embarked on a comprehensive initiative to conduct a fundamental investigation and cleanup of the “Four Mountains.” This concerted effort may rectify illegal constructions on these mountains and implement various projects that prioritize basic infrastructure and ecological protection restoration. In 2021, the 14th Five-Year Plan for Water Ecological Environment Protection in Liangjiang New Area (2021–2025) was issued by the Management Committee Office, Liangjiang New Area of Chongqing. The ecological restoration efforts in Chongqing have yielded remarkable results, leading to the transformation of the landscape into one characterized by “green mountains, beautiful water, lush forests, fertile fields, clean lakes, and green grass.” These positive changes have directly affected the lives of nearly 10 million people residing in the region. According to the 2021 Chongqing Ecological Environment Status Report, the water quality of the Yangtze River’s main stream section in Chongqing achieved an excellent rating, with all 20 monitoring sections being classified as category II. In 2021, Chongqing experienced a significant improvement in air quality, with a total of 326 days classified as having excellent or good air quality. Of these, 146 days were categorized as excellent, and 180 days were classified as good. The Chongqing’s pilot projects have integrated natural elements, such as mountains, waters, forests, fields, lakes, and grasslands, for systematic protection and restoration in the central urban area, resulting in several notable ecological restoration cases, including Guangyang Island and Tongluo Mountain. These projects have been
demonstrated to promote the green development of the Yangtze River Economic Belt, enhance the overall quality of the socio-economic-natural complex ecosystem, allow the city and ecosystem to integrate seamlessly, and realize the harmonious coexistence of humans and nature.

Liangjiang New Area is located in the main urban area of Chongqing, including parts of the three administrative districts of Jiangbei, Yubei, and Beibei. This area consists of 33 towns and streets with a total area of 1200 square kilometers. The overall terrain slopes down gently from the northwest to the southeast in the Yangtze River Valley, showing a distribution pattern of “the city in the south and mountains in the north”, a special terrain of “four mountains with three troughs”, and an ecological security pattern of “two rivers, four mountains, and multiple corridors”. Its ecosystem services are rich in variety (Figure 1) [32]. Despite this, Liangjiang New Area suffers from degradation in terms of its significant ecological resources, such as urban mountains, water bodies, and woodlands. Consequently, this severely damages ecosystem stability, environmental quality, services, and support capabilities.

Figure 1. Geographical location of the study area.

2.2. Data Sources

In this study, land use and land cover types were derived from Landsat OLI 8 remote-sensing images, while digital elevation model (DEM) data were obtained from the Geospatial Data Cloud. Precipitation and potential evapotranspiration data were obtained from the National Earth System Science Data Center, and soil data were obtained from the Harmonized World Soil Database. Nighttime light data were obtained from the Suomi National Polar-Orbiting Partnership-Visible Infrared Imaging Radiometer (NPP-VIIRS), and socio-economic and other statistical data were obtained from the Chongqing Statistical Yearbook, relevant statistical bulletins of Chongqing and Liangjiang New Area municipal governments, and government work reports.

2.3. Study Methods

2.3.1. Ecological Restoration and Ecosystem Services in the Country

National ecological land restoration and ecosystem services are closely intertwined and mutually influential. The activities undertaken for national ecological land restoration involve various measures, such as protection, improvement, guidance, optimization, reshaping, etc. These actions are aimed at conserving, cultivating, restoring, governing, or reconstructing the ecological aspects of the national territory. The impacts of national ecological land-restoration activities extend beyond altering the elements, structure, and spatial patterns of ecosystems. These activities also have implications for the long-term sustainability of regional ecosystem service losses and gains, as well as the overall supply
of ecosystem services. The changing balance of ecosystem service losses and gains, as well as supply and demand, necessitates trade-off assessments, adjustments, and control measures by different stakeholders involved in land management. In the pursuit of various ecosystem services, individuals carefully balance and optimize these services based on social needs, goals of land remediation and restoration, and the current status of ecosystem service supply and demand. This delicate process subtly influences the direction, objectives, planning, design, and zoning of national ecological land-restoration initiatives. The alterations made in land management practices and decisions are driven by the aim to obtain optimal ecosystem services while considering the complex interplay between ecological, social, and economic factors. Undoubtedly, the existing spatial differentiation characteristics of ecosystem services and zoning, as well as the matching of supply and demand, serve as the foundation for the development of regional modes and approaches for national ecological land restoration. These characteristics are also prerequisites for the sustainable utilization of land resources. In line with the current concept of constructing an ecological civilization and fostering a harmonious coexistence of mountains, waters, forests, fields, lakes, and grass, it is essential to adopt a methodological approach that incorporates ecosystem services when determining spatial zoning for national ecological land restoration (Figure 2). This research elucidates the reciprocal interaction mechanism between national spatial ecological restoration and ecosystem services. Subsequently, it puts forth national ecological land-restoration modes based on the ecosystem services, along with corresponding implementation strategies and measures. The overarching objective is to establish national spatial ecological security and foster the enhancement of ecosystem services, ultimately leading to regional sustainable development.

Figure 2. Study technology roadmap.

2.3.2. Calculation of Ecosystem Supply

Ecosystem services are derived from the concept of ecological carrying capacity [33] and have been expanded to encompass a range of direct or indirect benefits humans can obtain from ecosystems, such as food, water, and spirit [34]. Ecosystem services refer to
natural resources and human services that ecosystems can provide (Table 1) [35]. Using the InVEST model, four ecosystem services were selected for quantitative analysis: water yield, carbon storage, soil conservation, and habitat quality. The analysis results were normalized, followed by the weighting of synergies to evaluate the health status of the ecosystem and the spatial pattern of supply in Liangjiang New Area of Chongqing. The characteristics of ecosystem service supply patterns are summarized in Section 2.1.

Table 1. Calculation method of ecosystem services with the InVEST model.

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Formula</th>
<th>Variable Explanation</th>
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<tbody>
<tr>
<td>Water yield</td>
<td>$Y_x = \left(1 - \frac{AET_x}{P_x}\right) \times P_x$</td>
<td>$Y_{xj}$ refers to water yield ($m^3/hm^{-2}$), $P_x$ indicates annual average precipitation (mm), $AET_x$ is annual actual evapotranspiration (mm), $R_{xj}$ denotes the aridity index, and $w_x$ represents the empirical parameter of the natural climate–soil property relationship [36]</td>
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<tr>
<td></td>
<td>$\omega = Z\frac{AWC_x}{P_x} + 1.25$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\frac{AET_x}{P_x} = \frac{1 + w_x R_{xj}}{1 + w_x R_{xj} + \frac{R_{xj}}{P_x}}$</td>
<td></td>
</tr>
<tr>
<td>Soil conservation</td>
<td>$SC_i = RKLS_i - USLE_i$</td>
<td>SC$_i$ refers to soil conservation, RKLS$_i$ is potential erosion, USLE$_i$ denotes actual erosion, $R_i$ is the erosivity factor of precipitation, $K_i$ indicates the soil erodibility factor, $LS_i$ is the slope-length factor, $C_i$ represents the vegetation cover management factor, and $P_i$ is the water and soil-conservation measure factor [37]</td>
</tr>
<tr>
<td></td>
<td>$RKLS_i = R_i \times K_i \times LS_i$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$USLE_i = R_i \times K_i \times LS_i \times C_i \times P_i$</td>
<td></td>
</tr>
<tr>
<td>Carbon storage</td>
<td>$CS = C_{above} + C_{below} + C_{soil} + C_{dead}$</td>
<td>CS denotes the total carbon storage (t), $C_{above}$ refers to the aboveground biological carbon storage ($t/hm^{-2}$), $C_{below}$ represents the underground biological carbon storage ($t/hm^{-2}$), $C_{soil}$ is the soil organic carbon storage ($t/hm^{-2}$), and $C_{dead}$ indicates the carbon storage of dead organic matter ($t/hm$) [38]</td>
</tr>
<tr>
<td>Habitat quality</td>
<td>$Q_{xj} = H_{xj} \times \left[1 - \left(\frac{D_{xj}}{D_{xj} + k}\right)^2\right]$</td>
<td>$Q_{xj}$ represents the habitat quality index of plaque group $x$ in LULC type $j$: $D_{xj}$ donates the mean value of all threat levels of grid $x$, which will change due to the weight used; $H_{xj}$ refers to the habitat adaptability of grid $x$ in land-use type $j$; and the constant k is the half-saturation constant [39].</td>
</tr>
</tbody>
</table>

Water yield: The supply of water producing services is an indication of the amount of water produced in the study area and is the total amount of water produced through surface and subsurface aquifers within the catchment area in a given time period.
Soil conservation: an important safeguard to prevent regional land degradation and reduce the risk of flooding.
Carbon storage: an important component of regional carbon cycle research and can inform decision-making on regional carbon management for climate change mitigation.
Habitat quality: The ability of an ecosystem to provide survival conditions suitable for individuals and populations based on the availability of subsistence resources, the number of organisms reproducing and existing.

2.3.3. Calculation of Demand for Ecosystem Services

The degree of urbanization can reflect the demand of social systems for ecosystem services and the intensity of disturbance of human activities on ecosystems. A country’s need for ecosystem services varies according to its level of socio-economic development [40].

The demand for ecosystem services is closely associated with population agglomeration, economic development, and land development and utilization. In this paper, the indicator-based approach [41] was adopted in combination with the following: the ecosystem service value theory [42] proposed by [43]; the value equivalent factor table of China’s ecosystem services [44] developed by [45]; and the value of nighttime light intensity, land-use intensity, per capita GDP, and population density in Liangjiang New Area of Chongqing selected for classification according to the natural breakpoint method and the calculation of the demand for ecosystem services.

A higher value of the four indicators indicates a higher demand for ecosystem services. The intensity of land use reflects the use of different types of resources. Indirectly, nighttime light intensity and per capita gross domestic product indicate the degree of development of the regional economy and the demand for ecosystem services. The population density directly manifests the demand for ecosystem services. Due to the severe polarization of the economy, nighttime light intensity, and population, the natural logarithm method of statistics was used to mitigate the impact of violent fluctuations.

\[ Y_i = X_1 + \lg X_2 + \lg X_3 + \lg X_4 \]

where \( Y_i \) represents the total demand for ecosystem services of study unit \( i \), \( X_1 \) refers to the intensity of land use and development, \( X_2 \) denotes the population density (person/km\(^{-2}\)), \( X_3 \) means the per capita GDP (10,000 CNY/km\(^{-2}\)), and \( X_4 \) represents the mean value of the nighttime light intensity of the study unit (nW/cm\(^{-2}\)/sr\(^{-1}\)).

2.3.4. Supply–Demand Matching and Coordination Degree of Ecosystem Services

Based on the supply and demand of ecosystem services, the Z-score was standardized using variance [46], followed by the analysis of standardization results and spatial supply–demand matching. The results were classified into four types: high supply–low demand (supply > 0, demand < 0); high supply–high demand (supply > 0, demand > 0); low supply–high demand (supply < 0, demand > 0); and low supply–low demand (supply < 0, demand < 0) [47]. Bivariate local Moran indices represent the correlation status and spatial agglomeration degree between each attribute value on one spatial unit and its corresponding attribute value on the adjacent spatial unit. Analysis of local spatial autocorrelation was conducted using the bivariate model. The supply–demand balance relationship of ecosystem services was constructed [48] to explore the supply–demand spatial aggregation characteristics and the matching and coordination degree of ecosystem services in Liangjiang New Area [49]. Based on these principles, land spatial ecological restoration
strategies have been discussed in conjunction with the natural ecological characteristics, socio-economic status, and spatial planning of Liangjiang New Area of Chongqing [50].

$$LISA_i = \frac{(x_i - \bar{x}) \sum_j w_{ij}(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2/n \sum_j w_{ij}}$$

$$K = \sqrt{C \times (\alpha S_{\text{supply}} + \beta D_{\text{demand}})}$$

$$C = \sqrt{S_{\text{supply}} \times D_{\text{supply}} \prod (S_{\text{supply}} + D_{\text{supply}})/2}$$

where \(LISA_i\) refers to the bivariate local spatial autocorrelation index, \(w_{ij}\) denotes the spatial weight matrix, \(i\) represents the \(i\)-th unit street, \(j\) means the \(j\)-th adjacent unit street, \(x_i\) and \(x_j\) are the values (attributes) of \(x\) in adjacent paired spatial units (or grid cell), \(\bar{x}\) indicates the mean value of the attribute, \(n\) stands for the total number of streets in Liangjiang New Area of Chongqing, \(D\) refers to the coordination degree index, and \(C\) is the coupling degree. \(S\) and \(D\) represent the supply and demand of ecosystem services, respectively, and \(\alpha\) and \(\beta\) are coefficients.

3. Study Results

3.1. Characteristics of Ecosystem Service Supply Pattern

Ecosystem services in Liangjiang New Area were classified into five levels using the natural breakpoint method. Across the different ecosystem services, significant spatial differences were observed for each type of ecosystem service. Overall, the southwestern part of the state had a high level of water conservation, while the eastern and western parts of the state had a low level of water conservation. The high-value zones were mainly located along Tiangong Street, while the low-value zones were basically in Shijialiang Town. Generally, soil-conservation services were scattered, with areas of high value located on Huaxin Street and low-value sites located on Longshan Street. Carbon storage services and biodiversity generally presented a spatial pattern that was high in the northeast and low in the southwest, with the high- and low-value zones being on the Guojiatuo and Longxi streets, respectively (Figure 3).

The supply of the four types of ecosystem services displayed a spatial pattern of “high in the northeast and low in the southwest”. The high-value zones were mainly in the trough between Tongluo Mountain and Longwangdong Mountain, including Mu’er Town, Gulu Town, Wangjia Street, Yufengshan Town, and Guojiatuo Street. These zones’ ecological base and ecosystem functions were more stable, which was key to supplying regional ecosystem services. The low-value zones were mainly located in the southwest and southeast, including Caijiagang Street, Yuelai Street, Lijia Street, Kangmei Street, Renhe Street, Longshan Street, and Yuzui Town, with a faster pace of urbanization. On the central tableland, mountains such as Zhaomu, Huofeng, and Changling were occupied and subjected to deep excavation and high cutting during urban construction. The integrity of the mountains was poorly damaged in some areas, such as the Longgang and Fenghuang mountains, due to extensive industrial development and construction, as well as mountain occupation, resulting in a poor natural background of the zones and a low level of comprehensive supply of ecosystem services.
Figure 3. Spatial pattern of ecosystem services supply in Liangjiang New Area of Chongqing.

3.2. Characteristics of Ecosystem Service Demand Pattern

The demand for ecosystem services in Liangjiang New Area was divided into five levels using the natural breakpoint method, and significant spatial differences were observed between different types of ecosystem services (Figure 4). The land-use intensity and nighttime light showed a spatial pattern of “high in the southwest and low in the northeast”. The high-value zones were mainly located on Longta Street, while the low-value zones were distributed within Shichuan Town. The population density and per capita GDP presented a spatial pattern of “high in the south and low in the north”, with the high-value zones mainly discovered on Guojiatuo Street and the low-value zones in Shuitu Town and Shichuan Town.
The demand for ecosystem services in Liangjiang New Area presented a spatial pattern of “high in the southwest and low in the northeast”, with high-value zones mainly located on Tiangong Street and low-value zones located in Shichuan Town. In general, the demand was higher in zones with an agglomerated population, a high development intensity, and a developed economy. In contrast, the demand was low in zones with a sparse population, low development intensity, and an underdeveloped economy, displaying regular distribution.

3.3. Supply–Demand Relationship of Ecosystem Services

Ecosystem services in the Two Rivers New Area are mainly dominated by regulating services, with supporting services following closely behind. In Liangjiang New Area of Chongqing, there were four supply–demand matching modes of ecosystem services (Figure 5): the high supply–high demand matching type (quadrant I, 6 towns) zones; the low supply–high demand mismatching type (quadrant II, 15 townships) zones; the low supply–low demand matching type (quadrant III, 10 townships) zones; and the high supply–
low demand mismatch type (quadrant IV, 2 townships) zones. The zones accounted for about 20%, 25%, 4%, and 51% of the total area, respectively. The data suggest an apparent mismatch between the supply and demand of ecosystem services.

Figure 5. Supply–demand quadrant distribution and spatial distribution of ecosystem services in Liangjiang New Area of Chongqing.

Bivariate local autocorrelation was tested according to the supply–demand relationship of ecosystem services. It was found that the Moran index value was 0.5, which indicates a significant positive spatial correlation. The high–high agglomeration zones were located along the Shuangfengqiao and Shuanglonghu streets and in Shuitu Town, while the low–low agglomeration zones were located along Cuiyun Street and in Fusheng Town. This indicates a clear relationship between ecosystem service supply and demand, with less supplied areas having lower demand (Figure 6). The average index of Liangjiang New Area was calculated as 0.2 through the ecosystem services supply–demand coordination degree index formula. The supply–demand relationships between most zones appear to be unbalanced (Table 2).

Figure 6. Supply–demand coordination degree of ecosystem services in Liangjiang New Area of Chongqing.
Table 2. Supply–demand coordination degree of ecosystem services in Liangjiang New Area.

<table>
<thead>
<tr>
<th>Coordination Degree</th>
<th>Scope</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe incoordination</td>
<td>≥0.15 Gulu Town, Yufengshan Town, Shifun Town, Longxing Town, Muer Town, Fuxing Town</td>
<td>48.1%</td>
</tr>
<tr>
<td>Moderate incoordination</td>
<td>0.15 ≤ coordination degree ≤ 0.30 Fusheng Town, Yuzui Town, Shijiali Town, Caijiagang Street, Yuelai Street, Cuiyun Street, Lijia Street, Yuanyang Street</td>
<td>19.8%</td>
</tr>
<tr>
<td>Basic coordination</td>
<td>0.30 ≤ coordination degree ≤ 0.45 Shuangfengqiao Street, Wangjia Street, Shuitu Street</td>
<td>21.8%</td>
</tr>
<tr>
<td>Moderate coordination</td>
<td>0.45 ≤ coordination degree ≤ 0.60 Huixing Street, Baosheng Street</td>
<td>9.1%</td>
</tr>
<tr>
<td>High coordination</td>
<td>≥0.60 Jiangbei City Street, Huaxin Street, Guanyinqiao Street</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Based on spatial distribution, the areas with high supply–low demand and severe incoordination were primarily located northeast of Liangjiang New Area, where mountain ranges run from northeast to southwest. In particular, the Tongluo and Mingyue mountains have developed into stable and natural patterns. These zones have rich forests and developed forestry, with an abundance of ecosystem services. There was less development in the zones and less human interference due to the natural factors of topography and landform. In this regard, the demand for ecosystem services was low. Forests and water conservation areas should be protected in these areas and functional ecological conservation zones for planning purposes. The development of tourism resources and the development of ecological industries should also be encouraged. For example, functional zones can be set up in suburban leisure and ecological industry. Low supply–high demand and moderately uncoordinated zones were mainly distributed west of Liangjiang New Area, with flat terrain and predominantly urban and cultivated land. With intensified development, construction, and frequent human activities, there was high demand for ecosystem services. However, the supply of ecosystem services was lower due to the fewer land-use types such as woodland. The use of land in such zones should be intensive and economically planned. The ecological restoration and improvement of ecosystem service functions should focus on increasing land for ecological leisure and parks, with comprehensive consideration of the construction of ecological civilization and economic, social, and industrial development. Low supply–low demand zones and high supply–high demand zones were scattered and interspersed between the former two types as transition zones. Most of these zones exhibited basic, moderate, and high levels of coordination.

4. Optimization Strategies for Land Spatial Ecological Restoration Based on the Supply and Demand of Ecosystem Services

Based on the supply–demand spatial distribution, matching, and coordination of ecosystem services, the regional spatial development strategies were summarized by combining the Planning on the Liangjiang New Area Land Spatial Ecological Restoration (2021–2035), Planning on Land Space in the Liangjiang New Area of Chongqing (2020–2035), and Planning on Beautiful Landscape of the Liangjiang New Area. The functional orientation and the overall requirements of upper planning should be implemented to guide the definition of ecological restoration zoning and coordinate the layouts of nature, farmland, and urban systems. Assessments of the ecological foundation, the natural status, the ecological evaluation, and the socio-economic development of the area are crucial. It is essential that ecosystem restoration zoning considers both the supply–demand balance for ecosystem services and ecological issues and risks. It is essential to maintain the integrity of watershed units. A critical watershed or zone must be considered a basic unit to ensure the integrity and connectivity of physical geography and ecosystems. Consideration must be
given to the administrative unit’s integrity and continuity of the geographical division. The boundaries of the administrative villages should be taken as the minimum control units to comprehensively define the ecological protection and restoration zoning. Following an analysis of the regional situation, it was divided into four zones to carry out corresponding optimization strategies (Table 3).


<table>
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<th>Planning Guidelines</th>
<th>Supply–Demand Matching Characteristics</th>
<th>Supply–Demand Coupling Characteristics</th>
<th>Advantages of Current Natural Resources and Economic Industries</th>
<th>Problems of Current Natural Resources and Economic Industries</th>
<th>Key Optimization Strategies</th>
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<tr>
<td>Coordinate the relationship between urban construction and agricultural production, vigorously carry out comprehensive land consolidation in the whole zones, protect key ecological functions, and develop ecological leisure and high-tech industries</td>
<td>High supply–low demand</td>
<td>Severe incoordination</td>
<td>Better ecological and natural environment and sufficient supply of ecosystem services</td>
<td>Abandoned open mines, surface water-quality problems, and soil erosion</td>
<td>Ecological protection red line constraints, protection of ecosystem service functions, restoration of abandoned mines, and development of ecological industries</td>
</tr>
<tr>
<td>Coordinate the relationship between ecological protection and restoration and socio-economic development, protect the natural background, and build intelligent urban livable zones and an international ecological living room</td>
<td>Low supply–high demand</td>
<td>Basic coordination, moderate incoordination</td>
<td>Rapid urbanization and high population density</td>
<td>Fragile ecological background, weak resilience, and low supply of ecosystem services</td>
<td>Urban mountain restoration, governance of soil erosion and rocky desertification, comprehensive consolidation of human settlements, and development of intelligent ecological industries</td>
</tr>
<tr>
<td>Coordinate the relationship between urban construction and environmental protection and restoration, coordinate the harmonious coexistence between humans and nature, and build a high-quality ecologically livable highland</td>
<td>Low supply–low demand</td>
<td>Moderate incoordination</td>
<td>Abundant mountains and river resources</td>
<td>More unconstructed lands, less forest land and cultivated land, inefficient ecological land use, and more sensitive ecosystems</td>
<td>Reconstruction and improvement of the ecological environment, improvement of environmental quality, and development of ecological leisure industry</td>
</tr>
<tr>
<td>Hold the bottom line of ecological security; increase urban blue and green space; and build recreational, livable, green, and ecologically coordinated zones with sustainable development</td>
<td>High supply–high demand</td>
<td>Basic coordination, moderate coordination, High coordination</td>
<td>Better ecological background, less sensitive ecosystem with strong resilience</td>
<td>Mainly artificial ecosystems, occupation of ecological space by human activities in local areas, affecting ecosystem functions</td>
<td>Detailed planning of land-use layout, strict control of permanent basic farmland occupation for construction land, and comprehensive improvement of land in the whole zones</td>
</tr>
</tbody>
</table>

4.1. High Supply–Low Demand Zones

Most of these areas can be found in the northeast corner of Liangjiang New Area, including nine streets that account for 51% of the site. The supply of the four types of ecosystem services had a medium–high value, and the demand had a low value in these zones. All these zones showed a spatial matching pattern of “high supply–low demand”. In addition, such zones were rich in mountains and river resources, with abundant natural reserves and wetlands. However, abandoned open mines led to various problems, such as the destruction of vegetation, fragile forest ecological functions, and geological safety hazards. Phosphorus and total nitrogen in surface water exceeded their limiting values due to agricultural waste entering the water bodies, resulting in increased eutrophication. For such zones, the optimization strategy of “ecological protection red line constraints, protection of ecosystem service functions, restoration of abandoned mines, and development of ecological industries” should be adopted. In addition to the environmental protection “red line,” the creation of nature reserves, and the protection and conservation of ecosystem services functions, the Tongluo and Mingyue mountains should be protected...
for critical ecological functions, such as water conservation, biodiversity conservation, and soil conservation. The responsibility system of ecological environment protection and cultivated land protection should be established and perfected. Secondly, efforts should be made to enhance the quality of ecological restoration, including abandoned mines and precise improvement of forests. Thirdly, water-quality improvement, a connection of water systems, and restoration of shoreline resources should be carried out. Lastly, the carrying capacity of resources and the environment should be enhanced through rural surface pollution governance and comprehensive land consolidation.

4.2. Low Supply–High Demand Zones

These zones were primarily located west and southeast in Liangjiang New Area, with 14 streets accounting for 25% of the total area. The supply of the four types of ecosystem services and the demand were low. These zones presented a spatial matching pattern of “low supply–high demand”. The zones were growing at a higher rate than others, indicating that urban development has a detrimental effect on natural mountains. For instance, urban construction encroached on the Zhaomu, Huofeng, and Changling mountains.

Consequently, there has been deep excavation and high cutting, causing severe damage to the integrity of the mountains. For such zones, the optimization strategy of “urban mountain restoration, governance of soil erosion and rocky desertification, comprehensive consolidation of human settlements, development of intelligent ecological industries” should be adopted. First, urban construction should be coordinated with environmental protection and restoration. In order to ensure harmonious coexistence between humans and nature, the development of ecological space and urban space should be coordinated, and the responsibility for ecological and environmental protection and the quality of human settlements should be strengthened. Second, the Jialing River’s ecological boundary needs to be maintained, and the water system network needs to be conserved. A comprehensive environmental consolidation should be undertaken to enhance the functions of flood regulation and storage, as well as soil conservation. Thirdly, ecological barriers should be constructed in the water-fluctuation zone of small watersheds to maintain the stability of the shoreline of the watershed.

Consequently, the ecological environment of the urban riverside will improve. A multi-level “functional complex” riverside corridor system should be constructed to enhance the ecological services. In addition, there is a need to accelerate the industrial transformation to promote a digital and innovative economy. Additionally, it is necessary to establish an international ecological living room, a high-quality ecological living area, and a creative economic center.

4.3. Low Supply–Low Demand Zones

In Liangjiang New Area, these zones are primarily situated in the central and eastern parts, including two streets (Cuiyun Street and Fusheng Town), which together represent 4% of the area of Liangjiang New Area. The supply and demand of the four types of ecosystem services were all relatively low in the zones. These zones exhibited a “low supply–low demand” spatial matching pattern. No targeted and systematic environmental restoration governance was carried out in these zones after the mines were shut down. Due to this, the regional ecological environment was weakened, the ability of the mountains to conserve water was reduced, and there was severe soil erosion. For such zones, the optimization strategy of “reconstruction and improvement of ecological environment, improvement of environmental quality, and development of ecological leisure industry” should be adopted.

Firstly, the environmental quality should be enhanced by restoring natural vegetation and increasing the coverage of forests. Secondly, abandoned mines should be governed comprehensively, and the environmental carrying capacity of the ecosystem should be improved through engineering solutions, such as closing hills for afforestation and the rehabilitation of sloping land (for instance, the construction of horizontal terraces). Thirdly, the industrial structure of the zone should be adjusted. Innovative service industries, such
as commerce, industrial services, and ecological leisure, should be encouraged. Moderate development appropriate for local conditions should be encouraged.

4.4. High Supply–High Demand Zones

These zones were distributed in a dispersed manner. They were mainly located in the central and southern parts of Liangjiang New Area. The zones included nine streets that accounted for 20% of the area. The supply and demand of the four types of ecosystem services were all high, displaying a “high supply–high demand” spatial matching pattern. As typical urban construction zones, they were dominated by artificial ecosystems. Urban ecosystems accounted for a large proportion of these zones. Human activities were intense and comprehensive in parts of the zones. The zones occupied large ecological spaces and imposed negative impacts on the ecosystem. The protection pressure of the vital ecological barriers was high, and the quality of human settlements was degraded. For such land, the optimization strategy of “detailed planning of land-use layout, strict control of construction land occupation of permanent basic farmland, and comprehensive land improvement in the whole zones” should be adopted. Firstly, the regional-land-use structure should be adequately arranged through detailed planning. The boundaries between urban development, permanent protection of farmland, and ecological protection should be strictly regulated in order to maintain a balance between these three types of spaces. Secondly, the relationship between urban development and agricultural production should be balanced. It is crucial to implement a system of responsibility for farmland protection in order to limit the occupation of permanent basic farmland by construction activities. Thirdly, a comprehensive effort must be undertaken to consolidate the land and remediate polluted soil. Fourth, modern high-tech industries should be introduced in order to create an ecologically communal area of development that combines modern intelligent technologies with ecological construction.

5. Conclusions

The supply of ecosystem services in Liangjiang New Area of Chongqing presented a spatial pattern of “high in the northeast and low in the southwest”. Zones with higher ecosystem services had stronger ecological bases and better water conservation. Most of these were located in the Mu’er, Gulu, and Yufengshan towns. Generally, the land within areas with high ecosystem service demands was highly utilized and developed. The zones were also characterized by rapid socio-economic development and dense populations. A significant positive spatial correlation was found between the supply–demand matching relationship of ecosystem services in Liangjiang New Area of Chongqing, which was divided into four types: a high supply with high demand (9 streets); a low supply with low demand (2 streets); a low supply with high demand (14 streets); and a high supply with low demand (8 streets). In the Moran index, the value was 0.5, and the average index of supply–demand coordination degree was 0.2, indicating a severe lack of coordination between supply and demand.

In this study, an indicator system was constructed based on two main aspects of ecosystem services: regulating services and supporting services. The regulating services include climate regulation, ecological control, and flood control, while the supporting services include water cycle and soil formation and protection. To ensure the integrity of the ecosystem service assessment, the regulating and supporting services are combined to reflect the overall level of each ecosystem service function in the study area. Liangjiang New Area has been divided into four zones based on supply–demand relationships and ecological bases: high supply–high demand, low supply–low demand, low supply–high demand, and high supply–low demand. Overall, the optimization strategy of “ecological protection red line constraints, protection of ecosystem service functions, restoration of abandoned mines, and development of ecological industries” applies to the high supply–low demand zones for comprehensive ecological governance to improve the carrying capacity of resources and the environment. For low supply–high demand zones, the optimization strategy of “urban
mountain restoration, governance of soil erosion and rocky desertification, comprehensive consolidation of human settlement, and development of the intelligent ecological industry” should be adopted to balance the relationship between urban construction and environmental protection and restoration. As a result, human quality of life will improve, and there will be a harmonious coexistence between humans and nature. In the low supply–low demand zones, the optimization strategy of “reconstruction and improvement of the ecological environment, improvement of the environmental quality, and development of the ecological leisure industry” is preferred. As a result, it will improve environmental quality, while preserving an ecological system’s carrying capacity. The growth should be moderate and appropriate to the local environment. Moreover, the optimization strategy of “detailed planning of land-use layout, strict control of construction land occupation of permanent basic farmland, and comprehensive land consolidation in the whole zones” is recommended for the high supply–high demand zones. This will improve the quality of the living environment, integrate modern intelligent technologies with ecological construction, and build intellectually ecologically coordinated development zones.

An ecological restoration zoning and optimization strategy was developed based on supply–demand characteristics and the distribution of ecosystem services in Liangjiang New Area. In some ways, this study contributes to the existing research concerning the supply–demand relationship for small-scale ecosystem services led by intelligent innovation in new development zones located in mountainous cities. The study contributes to the knowledge of the ecological cognition of Liangjiang New Area and provides a practical guide for the restoration and planning of the ecological system in Liangjiang New Area. However, this study has several limitations. Firstly, from a temporal perspective, the supply and demand of ecosystem services can be further categorized into actual supply, potential supply, actual demand, and potential demand. Secondly, from a spatial perspective, ecosystem services have mobility characteristics, and different types of supply services may have certain trade-off and synergistic relationships in space. Additionally, this study acknowledges the potential impact of these factors and suggests that they were not fully considered. Furthermore, characterizing ecosystem service demand should go beyond a single-point assessment and take into account actual consumption patterns and preferences for different services. Lastly, the study recognizes the need to consider changes in the regional ecological environment and socio-economic conditions over time. In summary, future research can enrich the assessment framework by considering multiple indicators of ecosystem service supply, incorporating actual consumption patterns and preference biases into the characterization of demand, and accounting for the dynamic nature of the regional ecological environment and socio-economic conditions.

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