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Posted Date: 20 February 2025

doi: 10.20944/preprints202502.1597.v1

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Article

Research on Value Conversion Relationship and Appropriate Scale of Xinjiang Oasis Based on GEP and MOP Model

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Abstract: Soil and water resources are crucial for the stability and sustainable development of oases in inland arid zones. The conflict between socio-economic development and ecological environmental protection is a major challenge. Establishing a harmonious, stable, efficient, and sustainable oasis is key to balancing economic growth and environmental protection. This study evaluates oasis value through Gross Domestic Product (GDP) and Gross Ecosystem Product (GEP), revealing the current economic and ecological value of oases and the relationship between oasis value conversion in Xinjiang. This is achieved by combining land value transfer, oasis water-heat balance equation, and oasis value system, thereby assessing oasis stability and sustainability amid changes in value scale. The results indicate significant differences in the development trajectories of artificial and natural oases in Xinjiang since 2000. There has been a considerable expansion in the area and GEP of artificial oases, while the GEP of natural oases has continuously decreased. The land value transfer matrix reveals that converting ecological spaces to construction land and arable land has resulted in the loss of land GEP while simultaneously generating substantial GDP. The MOP model's optimization of oasis structures in each region indicates that areas like Aksu and Altay need to prioritize ecological security over the economic value of artificial oases. In contrast, regions like Bortala and Changji, with higher carrying capacities, can expand artificial oases to boost economic benefits without compromising ecological safety. This study offers a framework for evaluating and optimizing the value and sustainability of oases, playing a crucial role in balancing ecological security and socio-economic value in arid zones.

Keywords: gross ecosystem product; oases; economic benefits; ecological benefits; MOP model

1. Introduction

Oasis is a combination of natural and artificial complexes unique to arid zones [1]. As an inseparable part of the ecosystem, oasis is also the carrier of human economic development [2]. With the intensification of human activities, the continuous expansion of artificial oasis is accompanied by the decline of natural oasis, and the contradiction between the two is becoming more and more obvious [3,4]. To establish a harmonious, stable and sustainable oasis, there is an urgent need to find a balance between artificial and natural oases and research on the appropriate size of the oasis under the constraints of water resources. [5].

Maintaining the sustainable development of oasis and coordinating the relationship between economic development and environmental protection is impossible to avoid [6]. Initially, the negative effects of economic development on resources and the environment were first observed by researchers [7]. Later, the emergence of the "environmental Kuznets curve" corrected the view that economic growth will definitely bring negative impact on the ecological environment, and obtained the idea that economic development to a certain extent will help to improve the quality of the ecological environment [8]. However, it is difficult to grasp the balance of interests between economic

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development and ecological environment protection from the perspective of economic development or ecological protection [9]. After the opposing viewpoints, researchers have tried to maintain the coordinated development of economic development and environmental protection [10]. In the process of land development, the stability and balance of economic and ecological space is ensured by dividing ecological protection zones to avoid being destroyed [11]. Although this approach effectively protects ecological land, it also limits the space for land value enhancement.

After that, most of the research focused on exploring the mechanism of natural resources value preservation and appreciation to realize the win-win situation between economic development and environmental protection [12,13]. A series of relationship models of benign coexistence between economic development and environmental protection have been successively proposed and explained [14]. From the environmental Kuznets inverted U-curve relationship to the coupling of urbanization and ecological environment [8,15]. Scholars increasingly observe the possibility of organic unification of economic development and environmental protection. That is, through the revision of the original ecological space area, to guide the land use to the more valuable functional area change [16], and then realize the land value. The emergence of ecosystem gross product [17] opens up a new way of thinking for balancing the relationship between the two. It also provides technical guidance for exploring the transformational relationship between economic development and environmental protection [18].

The concept of gross ecosystem product (GEP) was proposed in 2013. It is defined as “the sum of the values of final goods and services provided by ecosystems for human well-being and sustainable economic and social development” [19].The GEP accounting framework is able to effectively quantify the value of ecosystem services, and transform ecological benefits into socio-economic benefits. It provides a scientific basis for the value of ecosystem services to be incorporated into the economic and social development assessment system [17]. Under the logic of the transformation of economic value and ecological value of land use. Scholars have developed from the beginning of the static analysis of the regional GEP accounting results [20] to the dynamic change analysis of the GEP accounting results of the study area year by year [13]. Some scholars have also explored the driving factors behind the dynamic changes in GEP [21]. Some studies consider the coupling of economic development and ecological security and evaluate the study area by constructing an evaluation index system. This helps us understand the relationship between economic development and ecology [22]. However, in the quantitative research on land value in the past, the practice is mostly to convert the “land value” into a weighted score “comprehensive evaluation index” or a single evaluation index through the model, which lacks the visualization of the amount of land value transformation. This leads to the limitations of the research results on the production practice.

Xinjiang is located in the inland arid zone, a vast area, the extreme scarcity of water resources makes the region desert. The ecological environment is very fragile and highly susceptible to human activities [22]. Under the conditions of policy support and accelerated urbanization in recent years, the continuous expansion of artificial oases has crowded out the living space of natural oases [23]. The overall area of oasis cannot be expanded indefinitely due to the limitation of water resources [24]. Under such conditions, the oasis in Xinjiang faces the dual tasks of ecological protection and high-quality development in sustainable development. In order to optimize the land use pattern of the oasis, researchers have searched for the carrying capacity limit through the ecological footprint method and the principle of system dynamics. And more satisfactory results have been obtained in Tarim River Basin and Shiyang River Basin [25,26]. With the increasing complexity and diversity of oasis land pattern changes, the coupled simulation model taking into account the structure-layout has become a hot spot of oasis land optimization research. For example, the MOP-CLUE model [27], the SD-FLUS model and the MCR- FLUS-Markov model [28,29] have provided scientific methodological support for the study of oasis land optimization. However, in the process of oasis land change, the contradiction between the increase of economic benefits and the loss of ecological benefits cannot be avoided. Methods such as ecosystem service value assessment based on land use change [30], statistical information and surveys [31], and parametric modeling have been gradually applied to the trade-off analysis of ecological and economic benefits of land [32]. However, in actual land use planning decisions, decision makers' preferences for different development goals often lead to different land use outcomes. Existing studies are prone to neglect the trade-off relationship between social, economic and ecological benefits under different development goal preferences [33]. Therefore, choosing multi-objective preference trade-off analysis and proposing the optimization scheme of future oasis land use pattern is more realistic operability and policy guidance.

In this regard, this study mainly considers the economic and ecological values of land use through GDP and GEP comprehensively. It explores the value transformation law between artificial oasis and natural oasis in Xinjiang. And through the multiple-objective programming (MOP) model to plan the future sustainable oasis structure, based on the above oasis value transformation relationship, analyze the future oasis value transfer. Provide scientific basis for the sustainable development of Xinjiang oasis region. It will help to promote the rational planning and protection of oasis resources in Xinjiang and realize the sustainable synergistic development of economic development and ecological environment.

2. Materials and Methods

2.1. Study Area

The study area is Xinjiang(Figure 1), with a total area of 1.66 million yuan km^2, located in the hinterland of the Eurasian continent, with a geographic location from 34°25′N to 48°10′N and 73°40′E to 96°18′E, and bordered by eight countries including Russia, Kazakhstan, Tajikistan, Afghanistan, Pakistan and India. As Xinjiang is far from the sea, it has a typical temperate continental arid climate with large temperature difference, sufficient sunshine time, low precipitation and high evaporation. Most rivers in Xinjiang are seasonal intermittent and rivers. Mountains surrounded by rolling hills of the terrain and blocked access to the sea, and eventually disappeared into the desert or pooled in the depression to form the tail break into the lake.

Oases are categorized into AO and NO. NO land-use types in the study area include forested, open forest, shrub, high cover grassland, medium cover grassland, lakes, beaches, and swamps. AOs include paddy fields, dry land, other forested land, construction land, reservoirs, and canals.Oasis in Xinjiang is mainly distributed in the basin and plains, of which AO is mostly distributed in the middle and lower reaches of the river, and NO is distributed in the lower reaches and the periphery of the AO [34].

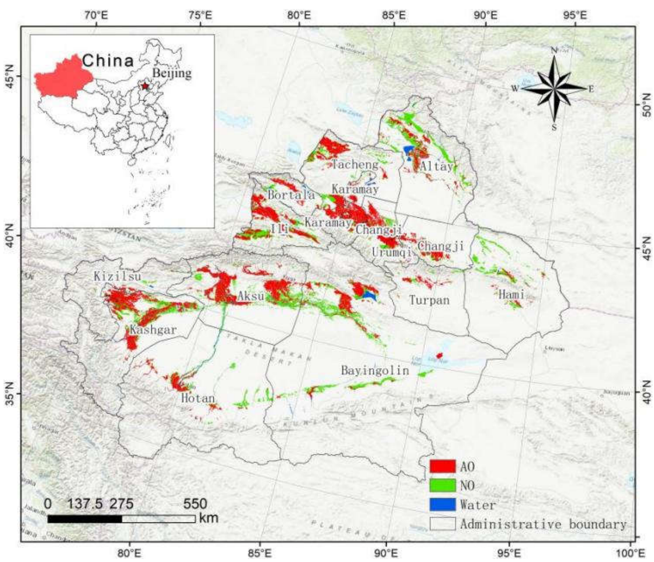

Figure 1. Xinjiang Location Map,China.

2.2. Data Sources

The data used in this study to calculate GEP include land use and statistical data. The land use data were obtained from the Center for Resource and Environmental Sciences and Data of the Chinese Academy of Sciences. (https://www.resdc.cn/) with a resolution of 30 meters. Statistical data on agriculture, forestry, animal husbandry and fishery, grain production and planted area are mainly from Xinjiang Statistical Yearbook (2001, 2011 and 2021) (https://tjj. xinjiang.gov.cn/). Water resources data and precipitation data are from Xinjiang Water Resources Bulletin(2001,2011and2021)(http://slt.xinjiang.gov.cn/).

The evapotranspiration (ET) data used to calculate the water-heat balance equations were obtained from the PMLV2 data of the Geospatial Data Cloud (http://www.gscloud.cn/) with a spatial resolution of 500 m. The NPP data were based on MODIS17A3 data and processed using the GEE platform. Group official website (http://www.ntsg.umt.edu). The price of reservoir capacity, carbon sequestration price, and oxygen production price were referred to the Specification for the Assessment of Forest Ecosystem Service Function.

2.3. Research Methods

This study investigates the changing relationship between GEP and GDP by calculating the GEP and GDP of different land uses in Xinjiang in different ages. Through the constraints of the MOP model, the amount of transformation between GEP and GDP under the future sustainable development conditions is accounted for. The research framework diagram is shown in Figure 2.

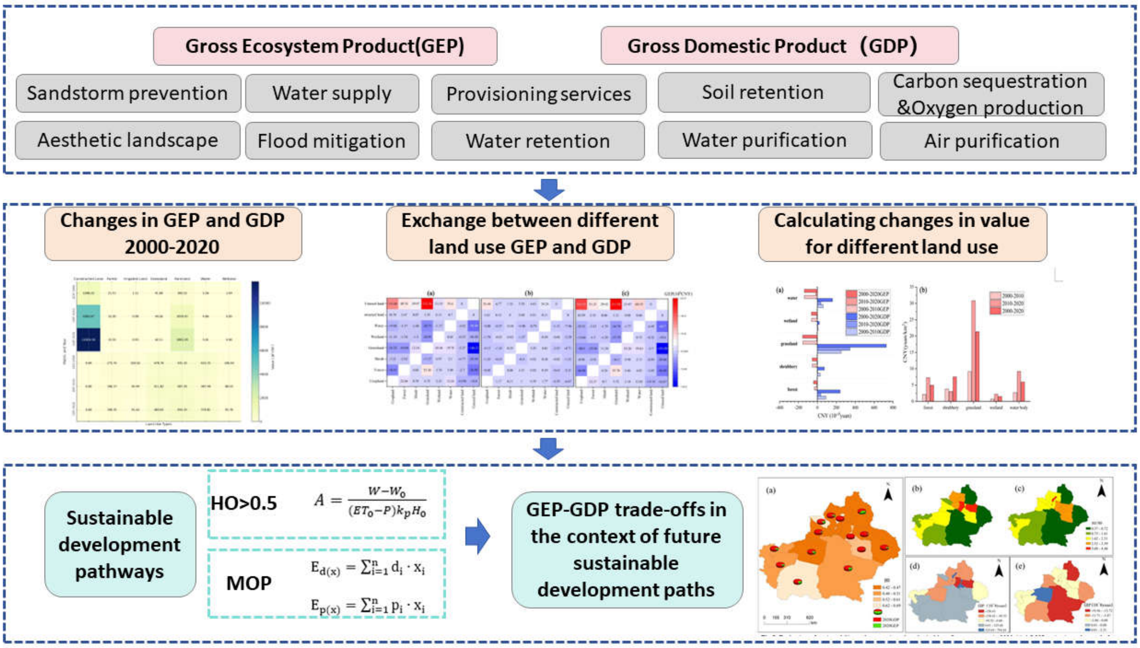

Figure 2. The framework of this study.

2.4. Technical Paths for the Conversion of Economic and Ecological Values of Land Use

The GDP and GEP indicators, which measure the economic and ecological value of land, were chosen as the main criteria for assessing the economic and ecological value of oases.It is worth noting that the economic and ecological values of oases do not directly originate from the land resources themselves, but rather from the spatial utilization patterns that give the land specific functional attributes and the compounding effects of human activities. Therefore, using GDP and GEP to measure the economic and ecological value of land is essentially an assessment of the value of spatial utilization outputs over the land cover [17].

The regional GDP is used as an indicator to assess the economic value of the oasis. The spatial scope of the assessment is positioned on construction land, versus arable land. It should be emphasized that although GDP reflects the overall economic scale of the entire regional area, the economic value of the land does not arise only from the construction land, and in order to be able to differentiate from the ecological value of ecological spatial land, the primary industry GDP in GDP is assigned to arable land, which includes the gross product of agriculture, forestry, animal husbandry and fishery, and the secondary and tertiary industry GDP is assigned to the construction land, which includes the gross product of GDP of construction, service industry, etc.

The ecosystem product GEP [35] was used as an indicator to assess the ecological value of land use. The spatial scope of land use ecological value assessment is the ecological land in Xinjiang, including forest land and grassland, water bodies and wetlands carrying natural ecological space, and cropland carrying artificial ecological space.

All tables should be numbered with Arabic numerals. Headings should be placed above tables, left justified. Leave one line space between the heading and the table. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which authors may find useful.

$$\mathrm{GEP} = \mathrm{EPV} + \mathrm{ERSV} + \mathrm{ECSV} \quad (1)$$

EPV means the value of ecological resource market products, *ERSV* means the value of ecological regulation services, and *ECSV* means the value of ecological cultural services.

2.5. GEP Accounting Framework

The GEP accounting framework of this study is divided into 3 major categories: supply service value, regulation service value, and cultural service value. It includes 10 items of product provision [19], water supply, water conservation [36]., flood storage [37], carbon sequestration and oxygen release [38], soil conservation [39,40], water purification [41], air purification, wind and sand control [42], and aesthetic landscape. Determine the calculation method and formula parameters for each functional value based on the characteristics of Xinjiang's mainly arid and semi-arid climate. Carry out GEP accounting and assessment of the study area (Table 1).

Table 1. Xinjiang GEP Accounting Indicator System.

Service types	Items	Methodology	Accounting metrics
Ecosystem production	Provisioning services	Market value approach	Value of agricultural, forestry, animal husbandry, and fishery products
	Water supply	Market value approach	Value of water for agriculture, industry, domestic use and ecology
Ecological regulation services	Water retention	Shadow engineering approach	Value of water storage effects in ecosystems
	Flood mitigation	Shadow engineering approach	Value of lakes, reservoirs, etc. for flood storage
	Carbon sequestration &Oxygen production	Alternative costing	Value of fixing carbon dioxide and releasing oxygen
	Soil retention	Alternative costing	The Value of Reducing Sedimentation and Reducing Face Source Pollution
	Water purification	Alternative costing	Value of ecosystems for purifying COD, total nitrogen, and total phosphorus

	Air purification	Alternative costing	Value of reducing concentrations of air pollutants and improving air quality
	Sandstorm prevention	Recovery cost method	The value of reducing soil erosion and wind-sand hazards
Ecological cultural services	Aesthetic landscape	Equivalent factor method	The value of landscape aesthetics

2.6. Value Transformation Analysis

On the basis of obtaining land use data, the two periods of spatial data were intersected and counted through the ArcGIS platform, and then the land use transfer matrix operation was used to obtain the number, structure and direction of the land use type transformation from 2000 to 2020. The land use transfer matrix is usually expressed in the form of a table, and its mathematical model expression is shown in equation (2) [43].

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} \quad (2)$$

where S_{ij} represents the land area of land type i transformed into land type j, n represents the number of land use types,. Type i and j represent the land use types at the beginning and the end of the transfer.

On the basis of obtaining the results of monetized measurement of economic and ecological values of land use, the economic value density Y_k (10^8 yuan/km^2) and ecological value density P_i (billion yuan/km2) of each land use are calculated as shown in Equation 21 and 22 [44].

$$Y_k = GDP/S_k \quad (3)$$

$$P_i = GEP/S_i \quad (4)$$

where Y_k represents the economic value density of land use, GDP is the GDP of k area, and S_k is the area of AO of k area; P_i represents the ecological value density of land use, and GEP is the GEP of i land class, and S_i is the area of i ecological land class.

Finally, the land use transfer matrix and land use value density calculation are combined to realize the transformation analysis of economic and ecological values of land use.The value transformation between ecospatial land use is calculated as equation 23. The value conversion of ecological land and construction land is calculated as shown in equation 24 and 25 [45].

$$V_{ij} = (P_j - P_i) \times S_{ij} \quad (5)$$

$$Q = Y_k \times S_{ik} \quad (6)$$

$$V = P_i \times S_{ki} \quad (7)$$

where V_{ij} represents the ecological value transformation amount from class i land to class j land, P_i and P_j represent the initial value density of class i ecological land and the final value density of class j ecological land. S_{ij} represents the transformation area. Where Q represents the gain or loss of economic value, Y_k is the economic value density of construction land k at the end of the study period. S_{ik} is the transformed area of the two types of land; V represents the gain or loss of ecological value, P_i is the ecological value density of ecological land of type i at the end of the study, and S_{ki} is the transformed area of the two types of land.

2.7. Model for Calculating the Appropriate Size of an Oasis

On the global scale, Hm is calculated based on the ratio of precipitation to evaporation potential to divide different climate environment zones. According to the principle of water-heat balance of ecology, put forward the index H_0 for evaluating the water-heat balance of oasis [46].

$$A = \frac{W - W_0}{(ET_0 - P)k_p H_0} \quad (8)$$

where A is the oasis area; W is the total amount of water resources available in the basin ; W_0 is the average annual water demand of industrial water, water for domestic use and ecological

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environment of the river in the basin; ET_0 is the amount of crop vacated according to Penman's formula for the calculation of the reference crop; P is the average annual precipitation in the basin; k_p is the comprehensive influence coefficient of the plants in the basin, which is the influence parameter reflecting the plant's own biological properties on the demand for water. $H0$ is able to reflect the degree of guarantee of oasis water resources on the change of oasis scale, and can be used as an indicator to determine whether the oasis is stable.

Combined with the results of on the stability of the oasis [47], the stability of the oasis is initially divided into four levels (Table 2).

Table 2. Evaluation grading of oasis stability.

Evaluation grade	H_0	Environmental change trend	Scale assessment
Ultra-stable	>0.75	High spatial heterogeneity	arger development potential
Stable	$0.50 \le H_0 < 0.75$	Remain stable	Can be further developed
Sub-stable	$0.20 \le H_0 < 0.50$	Beginning to degrade at the initial stage	No potential for development
Destabilized	<0.20	Degradation in progress	Exploitation and utilization should be reduced immediately

2.8. MOP Model

Multi Objective Programming (MOP) is a multi-objective planning model, which is one of the important models to study the optimization of land use structure [48].MOP can combine economic, ecological and some variables based on the planner's own needs, which are considered by defining the objective function and constraints, and the constraints of the objective function are shown in Table 1. In this study, two optimization objectives are defined: ① max Ed(x) to maximize economic benefits; ② max Ep(x) to maximize ecological benefits, and the optimization objectives of MOP are as follows.

$$E_{d(x)} = \sum_{i=1}^{n} d_i \cdot x_i \quad (9)$$

$$E_{p(x)} = \sum_{i=1}^{n} p_i \cdot x_i \quad (10)$$

where $E_{d(x)}$ and $E_{p(x)}$ represent economic and ecological benefits, respectively; x_i represents the variable of the i class (i=1, 2,..., 7); d_i and p_i are the coefficients of economic and ecological benefits of the class per unit area. To obtain the optimal land use structure, these two objectives need to be maximized at the same time.

3. Results

3.1. Comprehensive Evaluation of Oasis Economy and Ecological Value

Over the last twenty years, the development trends of AO and NO in Xinjiang have significantly diverged(Table 3). From 2000 to 2010, the GDP of artificial oases in Xinjiang soared by 463.23 billion yuan, a 352.88% increase. This growth continued from 2010 to 2020, with an increase of 785.24 billion yuan, or 132.08%. Concurrently, their GEP and area increased by 34.94% and 37.76%, respectively. Additionally, their value density grew by 171.28% and 98.54% over these two decades. In contrast, natural oases showed a declining economic trend, with a 6.15% decrease in GDP and 9.55% in GEP during the same period. While the area of natural oases generally decreased, their value density saw a modest increase of 2.60% from 2010 to 2020. This data highlights the consistent growth of artificial oases in Xinjiang and the challenges confronting natural oases.

Table 3. Evaluation grading of oasis stability.

Year	Type	GDP (10^8yuan)	GEP (10^8yuan)	Area (km^2)	Density (10^4yuan/km^2)

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2000	AO	1312.74	435.16	65383.32	267.33
	NO	70.91	1390.71	78567.46	186.03
2010	AO	5945.09	587.19	90072.74	725.22
	NO	66.55	1257.94	75755.81	174.84
2020	AO	13797.58	656.30	100387.01	1439.82
	NO	64.27	1241.98	72819.97	179.38

Considering that land use ecological value assessment encompasses six land types, this study offers a comprehensive analysis of this assessment. Between 2000 and 2020, the GDP and GEP changes for different land use types within Xinjiang's oases varied significantly (Figure 3).

Overall, the GDP saw a significant rise from 138.36 billion yuan in 2000 to 1,386.19 billion yuan in 2020, whereas the GEP experienced a modest increase from 182.58 billion yuan to 189.83 billion yuan. For specific land use types, construction land's GDP rocketed from 100.62 billion yuan in 2000 to 1,181.63 billion yuan in 2020, marking a 527.4% growth. The GDP of cultivated land escalated from 30.65 billion yuan to 198.13 billion yuan, an increase of 546.6%. Meanwhile, the GDP of forests, shrubs, grasslands, water bodies, and wetlands exhibited relatively stable changes, with growth rates varying from -28.87% to 6.91%. The GEP of cropland increased from 43.51 billion yuan to 58.71 billion yuan, a growth rate of 34.9%. In summary, over these two decades, the remarkable growth in construction and cultivated lands significantly enhanced the GDP contribution of various land use types in the Xinjiang oasis, while the GEP changes for each land use type remained relatively stable.

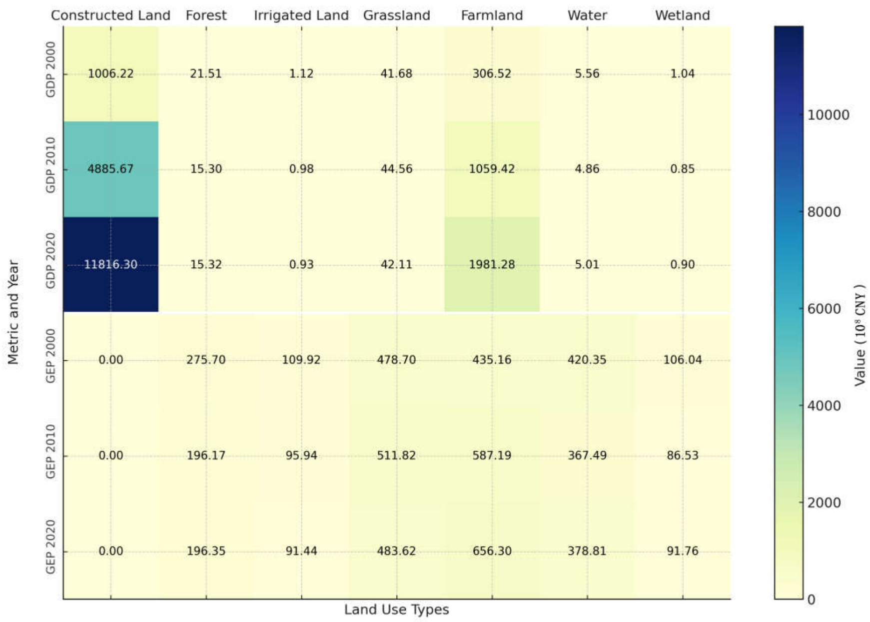

Figure 3. Economic and social values of different land use types in Xinjiang, 2000-2020.

3.2. Characteristics of Positive and Negative Flow of Oasis Land Value

In land use change, the land's value resembles a "value vector," possessing both magnitude and direction. Previously, we derived the "value vector" from the dual calculation of GDP and GEP, while its directional shift was determined by the land use type shift matrix. In this analysis, we'll integrate the directional shifts in land use types with the average value data of each land type to fully illustrate the flow characteristics of land use values in the Xinjiang oasis. From 2000 to 2020 (Figure 4), the flow characteristics of oasis ecological values exhibited a distinct positive and negative divergence. Between 2000 and 2010, the net transfer was 14.11 billion yuan, with unused land displaying a pronounced positive transfer trend and a total transfer of 48.89 billion yuan with other land types. However, from 2010 to 2020, the ecological value flow of unused land decreased to 9.68 billion yuan.

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Grasslands and forests, both key ecological land types, demonstrated significant transfers with other land types in both periods. From 2010 to 2020, there was a notable shift from water bodies to wetlands, closely associated with national and local water conservation and wetland restoration policies. Additionally, from 2000 to 2020, the transfer from unused land to other land types amounted to 54.60 billion yuan. These data reveal not only the positive flow characteristics of wasteland during a specific period but also highlight its substantial potential for ecological value.

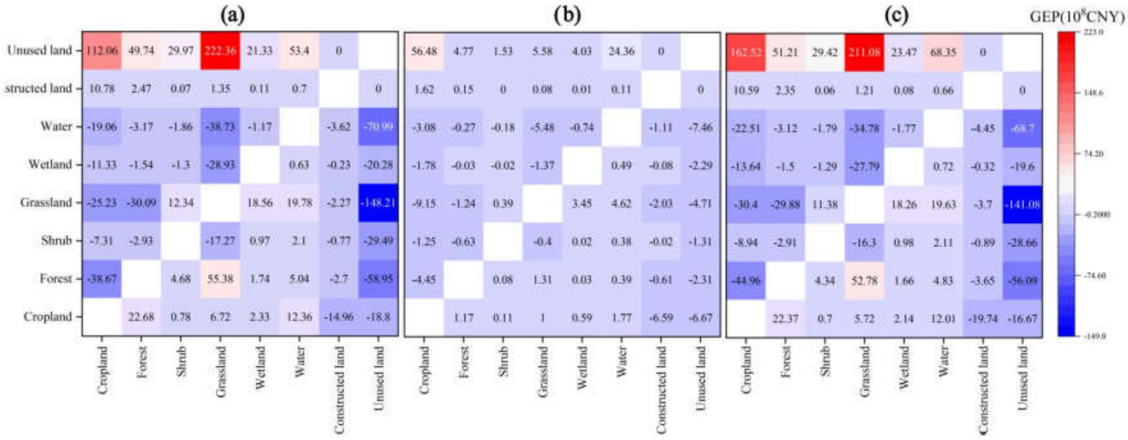

Figure 4. Ecological value flow of oases,2000-2020 (a),2010-2020(b),2000-2020(c).

3.3. Transformation Relationship Between Oasis Economic Value and Ecological Value

Converting ecological spaces into construction and cultivated lands results in a loss of ecological value, but it also significantly increases economic value (Figure 5a).Between 2000 and 2020, changes in land use methods resulted in a 122.37 billion yuan increase in economic value and a 13.35 billion yuan decrease in ecological value. This suggests that for every one yuan decrease in ecological value, economic value increases by 9.17 yuan. the conversion of forests, shrubs, grasslands, wetlands, and water bodies led to economic growth of 24.06 billion yuan, 7.39 billion yuan, 72.82 billion yuan, 2.10 billion yuan, and 16 billion yuan, respectively. Correspondingly, for every yuan decrease in ecological value, these land types contributed 4.95 yuan, 7.51 yuan, 21.35 yuan, 1.50 yuan, and 5.94 yuan to economic growth. (Figure 5b).

A phased analysis from 2000 to 2010 shows that changes in land use methods led to a 44.06 billion yuan increase in economic value and a 11.12 billion yuan decrease in ecological value. For each yuan reduction in ecological value, economic value increased by 3.96 yuan. The conversion of forests, shrubs, grasslands, wetlands, and water bodies resulted in economic growth of 8.97 billion yuan, 3.06 billion yuan, 25.07 billion yuan, 0.84 billion yuan, and 6.13 billion yuan, respectively. Additionally, for every yuan reduction in ecological value, these land types contributed 2.17 yuan, 3.78 yuan, 9.11 yuan, 0.73 yuan, and 2.70 yuan to economic growth.

From 2010 to 2020, due to the GDP increase, the economic value per unit of land was higher than the previous period, resulting in more economic value from land use changes. Overall, there was a 42.78 billion yuan increase in economic value and a 2.36 billion yuan decrease in ecological value. For every yuan decrease in ecological value, economic value increased by 18.14 yuan. Correspondingly, for every one yuan decrease in ecological value, these land types contributed 7.26 yuan, 3.02 yuan, 30.80 yuan, 2.22 yuan, and 9.17 yuan to economic growth.

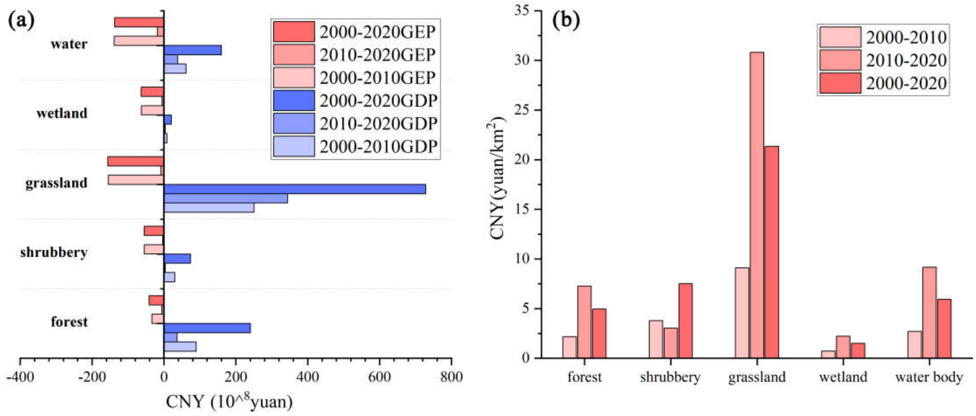

Figure 5. GEP and GDP changes of different land types from 2000 to 2020(a), and the increase in GDP per unit of land change(b).

3.4. Analysis of Value Changes after Optimizing Structure Based on MOP Model

The framework for future sustainable development of oases is established by applying constraints to the objective function of the MOP model. Given the varied conditions across Xinjiang's regions, the model was employed to categorize constraints and objectives by region, determining the proportion of oasis that fits the sustainable development model in each area. Integrating the aforementioned relationship between economic and ecological benefits, the trends in economic and ecological benefits of the oasis pre- and post-planning were finally calculated (Table 4).

Table 4. Limitation conditions of objective function of MOP model.

Constraint Name	Constraint Factor	Constraint Expression	Explanation
Land sustainable utilization constraint	Land area	$X_1 + X_2 + \ldots + X_7 \leq \frac{W - W_0}{(ET_0 - P)k_p \cdot 0.5}$	When HO>0.5, it is sustainable utilization state.
Planning target constraint	Cropland	$X_1 \geq$2020 cropland area	Binding indicators
	Forest	$X_2 \geq$2020 forest area	Binding indicators
	Grassland	$X_3 \geq$90%·2020 grassland area	Binding indicators
	Wetland	$X_4 \geq$90%·2020 grassland area	Binding indicators
	Water	$X_5 \geq$2020 grassland area	Binding indicators
	Shrubs	$X_6 \geq$90%·2020 grassland area	Binding indicators
	Construction land	$X_7 \geq$2020 grassland area	Binding indicators

The evaluation of oasis stability across Xinjiang reveals that 50% of the regions are sub-stable, particularly in Changji, Tacheng, and Yili, while the other 50% are stable, notably in Karamay, Hotan, and Bole, with Altay, Aksu, and Bazhou having the highest share of ecological benefits (Figure 6a).

According to the ratios of artificial to natural oases (Figure 6b, c), in regions like Aksu and Altay, the area ratio is expected to decrease from 1.70 to 1.52 and from 0.53 to 0.37. Conversely, in regions like Bortala and Changji, this ratio is expected to rise from 1.36 to 2.35 and from 3.83 to 3.59, respectively. Economically (Figure 6d), changes are also anticipated in these regions, with Aksu and Altay expected to see decreases of 128 million yuan and 113 million yuan, respectively, while Bayinguoleng and Bortala are projected to see increases of 132 million yuan and 232 million yuan.

On the ecological front (Figure 6e), Aksu's ecological benefits are expected to see a slight increase of 2.31 million yuan, while those in Altay and Bayinguoleng are projected to decrease by 13.72 million yuan and 1.96 million yuan, respectively. Bortala's ecological benefits are also anticipated to decrease slightly, by 3.87 million yuan.

These dynamics underscore the complex interaction between economic development, ecological sustainability, and the role of artificial oases. The varying trends across regions highlight the necessity for tailored strategies to balance economic growth and ecological management, guiding changes in oasis landscapes with a long-term view and a focus on sustainable development.

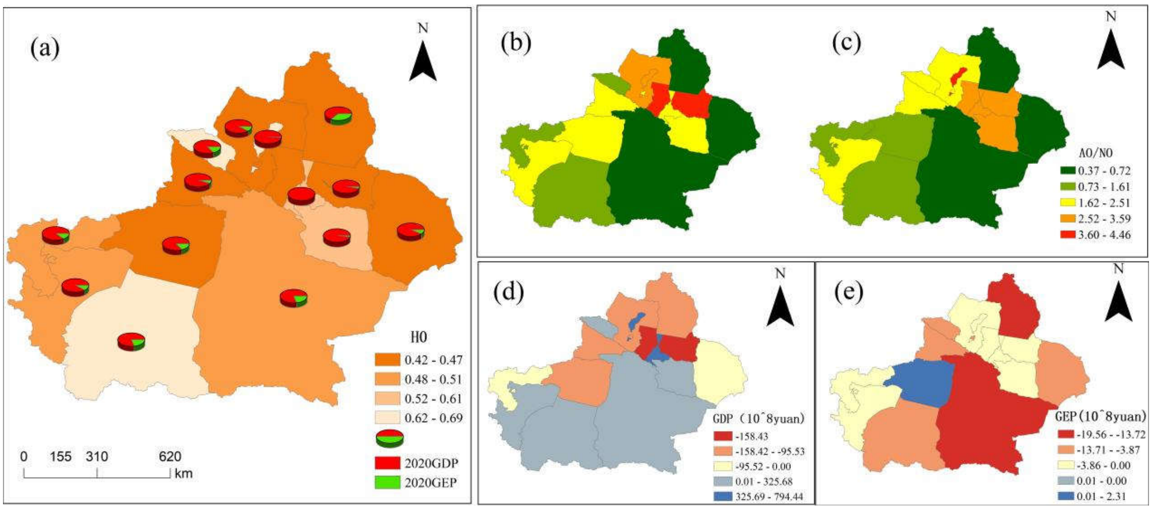

Figure 6. Evaluation of oasis stability and economic and ecological benefit components in 2020 (a),AO/NO ratios in each state before and after planning, pre-planning (b), post-planning (c), amount of change in GDP before and after planning (d), amount of change in GEP (e).

To sustain oasis development, the MOP model, considering H0>0.5, provides insights into land type structure and economic transformation in each region before and after optimization (Figure 7). Future development trends vary across regions. Regions with larger ecological values, like Bortala Mongol Autonomous Prefecture, have more development potential. Here, the artificial to natural oasis ratio rose from 1.36 to 2.35, reducing ecological benefits by 386 million yuan but yielding 2328 million yuan in economic benefits. Conversely, in the Aksu region, the artificial to natural oasis ratio decreased from 1.70 to 1.52, leading to a loss of 12813 million yuan in economic benefits but compensating with 230 million yuan in ecological benefits. High economic density areas like Urumqi and Karamay will gain higher benefits from land structure adjustments. Meanwhile, less economically dense regions will need to relinquish more natural oasis area to achieve a corresponding rise in economic benefits.

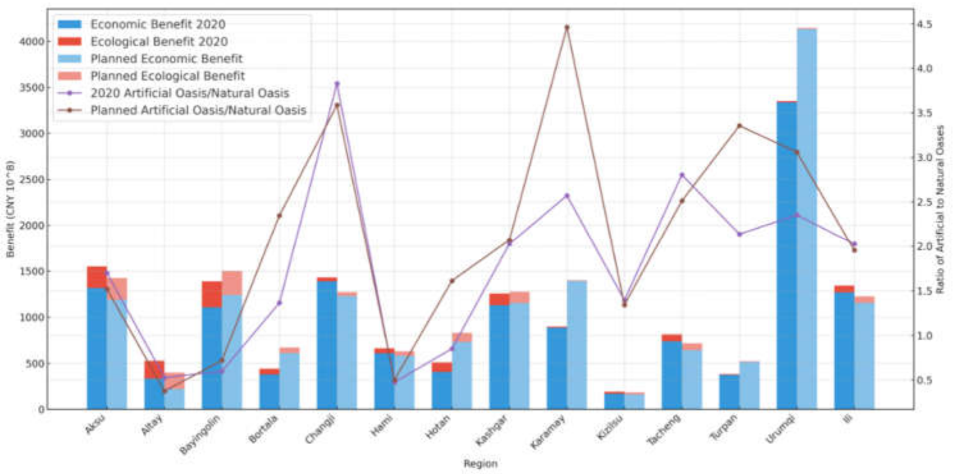

Figure 7. Changes in the relationship between ecological and economic benefits and AO/NO ratios before and after planning.

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4. Discussion

4.1. Unbalanced Development of Oasis Economy and Ecological Value

The growing conflict between social and ecological water use in Xinjiang makes finding a balance challenging. To reverse this and enhance oasis stability while boosting the local economy and preserving ecology, it's essential to optimize the ecosystem and improve ecological carrying capacity. This requires a rational oasis structure, balancing both aspects to achieve green development in both ecology and society [49].

This study prioritizes water as the key element of oasis development, proposing maximum carrying values for oases in each basin and calculating their GDP and GEP using the MOP model. This approach also allows for determining the optimal proportion of oasis development. The results reveal varying ecological and economic values of oases in each region, with a comprehensive analysis underscoring significant regional differences in economic prosperity and ecological balance. This highlights the urgent need for targeted sustainable development strategies. For instance, the sharp contrast between Changji Prefecture's economic strength at 138.7 million yuan and Altay's lower economic figure of 334 million yuan illustrates the uneven distribution of wealth and resources. This economic imbalance also manifests in ecological benefits; Bayin'guoleng's ecological benefits total 280 million yuan, exemplifying ecological balance, whereas Changji Prefecture, despite its robust economy, falls short in ecological advantages.In Changji, the imbalance between economy and ecology is evident, with an artificial to natural oasis ratio of 3.83, raising concerns about the sustainability of its development model. This situation underscores the importance of integrating ecological considerations into economic planning and points out the potential risks of overlooking environmental health in pursuit of economic growth.

As per the MOP model, the projected shift in the ratio of artificial to natural oases in future planning indicates a deliberate change in regional development strategies.In Bortala, this ratio significantly increases from 1.36 to 2.35, suggesting a preference for artificial oases, possibly motivated by economic incentives.Conversely, in Changji, the ratio slightly decreased to 3.59, indicating a possible reevaluation and shift toward natural oasis restoration, aligning with Xinjiang's sustainable development objectives.

4.2. Countermeasures for the Sustainable Development of Oasis Economy and Ecological Values

Currently, certain areas must preserve natural oases by reducing artificial ones, leading to a trade-off between economic and ecological values. This can be balanced using ecological compensation and occupancy balancing, mitigating the adverse effects of reduced economic value. Essentially, when a site's ecological value must yield to economic development, compensation for ecological loss or reconstruction of ecological value at alternative sites can ensure a balance between the site's economic and ecological values. Implementing an ecological compensation system, the relationship between a site's economic and ecological values guides compensation for economic loss in areas where ecological value has diminished due to ecological damage [50]. In regions lacking resources, the disparity in oasis value can be compensated with measures like water conservation and external basin water transfers [14].

4.3. Future Development Trend of Oasis Structure

Considering the results of the above analysis, the future development and utilization of oasis soil and water resources in Xinjiang indicate these trends: (1) Artificial oases also retain some ecological value of natural oases. Sustainable development of oasis structures, through rational planning of oasis ratios, aims to enhance socio-economic value, achieving a win-win for both ecology and society. (2) The stability of oases in Northern Xinjiang is lower than in Southern Xinjiang, and the water produced in Northern basins is inadequate for the demand, while Southern Xinjiang's water resources mostly meet regional needs. Hence, greater attention should be paid to the benefits of water conservation measures. The region must capitalize on this opportune period to initiate

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economic transformation, modify its water use structure, balance economic and ecological factors, and guide oasis landscape transformation with a focus on foresight, resilience, and sustainability.

5. Conclusions

(1) Analysis from 2000 to 2020 reveals significant developmental disparities between Xinjiang's artificial and natural oases. Artificial oases saw substantial economic growth, with GDP surging by 463.24 billion yuan (2000-2010) and 785.25 billion yuan (2010-2020), alongside notable expansions in area and GEP. Conversely, natural oases encountered economic and ecological setbacks, experiencing a 6.15% decline in GDP and 9.55% in GEP, despite a marginal 2.60% increase in value density from 2010 to 2020.

(2) A detailed assessment of the ecological value across six land-use types further uncovers nuances and disparities between GDP and GEP, underscoring the complexity of sustainable development in the region. This includes a particularly marked increase in the contribution of built-up land to GDP relative to agricultural land, and relatively stable changes in GEP across various land-use types. These findings highlight the urgent need for targeted interventions and policies to promote balanced growth and ecological management across various oasis types and land use categories.

(3) The conversion of ecological spaces into construction land and arable land resulted in ecological value loss, while simultaneously generating significant economic value. Over 20 years, the transfer from NO to AO decreased ecological value by 13.35 billion yuan and increased economic value by 122.37 billion yuan. The expansion of AO compensated for the decline in NO's GEP, leading to an overall increase in GEP. This reflects a delicate equilibrium between economic growth and ecological protection. Data indicates that various land types contribute distinctly to this shift. Forests and grasslands, in particular, demonstrate the most substantial economic growth per unit of ecological value reduction. Between 2010 and 2020, this trend shifted, with the rate of economic growth per unit of ecological value reduction decreasing in 2010 but increasing significantly by 2020.

(4)Optimizing the oasis structure through the MOP model reveals that development trends vary across regions. In Aksu and Altay, the ratio of artificial to natural oasis must decrease, which will also lead to a decline in economic benefits.In regions like Bortala and Changji, the ratio of artificial to natural oasis and economic benefits are expected to increase, suggesting that expanding artificial oases for economic growth may come at the cost of a portion of the natural ecosystem.

Author Contributions: Ziyu Long: Writing- review & editing, Project administration, Supervision, Methodology, Funding acquisition, Conceptualization. **Xudong Wang**: Writing-original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization.

Funding:

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement: Data will be made available upon request. If there is a need for data from this study you can contact the author,

Acknowledgments: This research was supported by the National Natural Science Foundation of China.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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