Evaluation and Planning Application of Oasis Habitat Stability in Arid Regions Based on the PPSD Model:
A Case Study of Wensu County, Xinjiang.

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Abstract: Oasis regions, with high population and wealth density, are vital for human habitation and ecological balance in arid areas, where their stability and sustainability are crucial for human habitation and ecological balance. Current research on oasis stability often focuses on the impact of natural and human factors on oasis systems, overlooking the interactive and dynamic role of human and natural facts as both enhancing and demanding entities from these ecosystems. This study introduces the PPSD (Promotion-Pressure-Support-Destruction) model to comprehensively assess human and natural influences on oasis stability. It quantifies human actions' promotion(such as water infrastructure and traffic development) and pressures (resource consumption and development intensity) on oases, as well as natural support (water, land, biodiversity) and destructive forces (disasters, climate). The study takes Wensu County in Xinjiang as the research subject, and reveals that the stability scores of the existing oasis regions in Wensu County are relatively high, with notable performance in the northwest of the western oasis and the south, east, and north of the eastern oasis. By analyzing the spatial distribution of 16 different combinations of the four forces, the county is divided into eight ecological zones: nature reserves, ecological improvement areas, maintenance zones, restoration areas, natural retention belts, natural development potential areas, and potential developing areas. Planning and conservation suggestions are proposed for each zone. Finally, integrating stability analysis with planning, a strategy for Wensu's oasis development is suggested, advocating for "optimize the western area along the Kumal River, control northern development towards the Hamantala Mountains, extend the eastern area of Qingnian Town, and connect the southern with the Aksu region." along with a phased land use planning and development sequence based on the suitable scale of the oasis.

Keywords: Oasis Stability; PPSD Model; Human-Nature Influence; Wensu County

1. Introduction

Oases, characterized by stable water sources and conducive conditions for plant growth, exhibit significantly higher vegetation coverage and productivity compared to the surrounding deserts. They form unique geographical landscapes within arid regions that are suitable for human habitation[1, 2]. As the most densely populated and crucial spatial carriers within arid zones, oases are the primary areas for human activity. Based on their formation and the extent of human intervention, oases can be categorized into two types: artificial and natural[3]. Natural oases are areas that have formed and developed under natural conditions, with minimal human influence. In contrast, artificial oases are regions where humans have intervened to alter the structure of the original desert or natural oasis, thereby enhancing productivity.

Current research has primarily focused on the quantitative characterization and evaluation of oasis stability, its influencing factors, and its spatiotemporal evolution within the scope of study. In the identification of stable states, water use efficiency and primary productivity (biomass) are the main indicators for recognizing the stable state of an oasis[4]; In terms of quantitative characterization, existing studies utilize landscape pattern indices, agricultural water footprint indices, hydrothermal equilibrium, land use intensity indices, and oasis cold island effects to quantitatively analyze oasis stability[5–9]; The establishment of an evaluation system for oasis stability mainly involves the construction of a multi-indicator system from the perspectives of ecological environment, socio-economic factors, and natural disasters within a complex system[10,11]; The influencing mechanisms focus on the quantitative impact of water resources in arid regions on oasis stability[12,13]; Regarding the spatiotemporal evolution of oasis stability, a gridded oasis spatial dynamics model has been developed to explore patterns of stability changes over extended periods[14].

Oases, which cover only 3-5% of the area of arid regions in China, are home to over 90% of the population and more than 95% of the social wealth in these areas[15]. From 1990 to 2020, the total area of oases in the Xinjiang region of China increased from 157,000 km² to 171,000 km². During this period, there was a reduction in the area of natural oases and an increase in artificial oases, with the ratio changing from 1:0.65 to 1:1.3. By the year 2020, artificial oases accounted for approximately 56.52% of the total oasis area[16]. Human intervention can improve irrigation conditions, increase the area and productivity of oases, but it may also exacerbate severe issues such as water resource scarcity, grassland desertification, soil salinization, river basin disruption, and desertification[17 - 19]. Oases exhibit a hydro-centric nature in terms of natural resources, where the presence of water defines an oasis, and its absence leads to desertification[21]. Moreover, they are ecologically fragile, being macroscopically encircled by vast deserts and Gobi[22].

Therefore, understanding the mechanisms of stability and sustainability of oasis habitats is crucial for their development, utilization, and ecological restoration efforts. The essence of oasis stability is a matter of harmonizing the relationship between humans and the land, a complex interplay involving socio-economic development and environmental protection among multiple forces[20]. Building upon previous research, this paper constructs the PPSD (Promotion-Pressure-Support-Destruction) interactive force theory model to analyze and evaluate the stability of the human-land relationship system in oases. It identifies regions where the oasis is in a stable state, assists in determining the direction of urban development and the scale of land use, and explores new pathways to achieve a balance and sustainable development between natural ecology and human exploitation.

2. Model Methods

2.1. Conceptual Model

Humanity has long recognized the finite nature of Earth's space and resources, as well as the importance of harmonizing the relationship between humans and the environment. Currently, researchers both domestically and internationally have proposed various models that take into account the positive and negative impacts of human activities on the natural environment, as well as the feedback of natural resources in terms of quality and quantity. Common models include the

PSR (Pressure-State-Response) model, the DPSIR (Driving Force-Pressure-State-Impact-Response) model, and the DPSEEA (Driving Force-Pressure-State-Exposure-Effect-Action) model, etc. [23]. The PSR model can clearly depict the causal relationships within a system, but its choice of indicators relies on the professional intuition and experience of the researchers, which is subjective. It performs poorly when dealing with complex feedback systems[24–27]. The DPSIR and DPSEEA models, starting from a comprehensive perspective of the human-environment system, supplement and improve upon the PSR model[28,29]. However, they still focus on the traditional "reactive" concept of environmental protection[30] and lack a forward-looking evaluation and analysis. Wang Liang et al. [31] proposed the PS-DR-DP (Pressure-Support; Destructiveness-Resilience; Degradation-Promotion) hexagonal interactive force model, which simulates the dynamic changes of the resource and environmental carrying capacity to form a "forward-looking" evaluation mechanism. However, this model has issues such as unclear relationships between the six forces and their primary and secondary subjects, and redundant indicator dimensions. Therefore, this paper introduces the PPSD (Promotion-Pressure-Support-Destruction) model, which returns to the relationship between humans and nature within the oasis spatial carrier's system. It categorizes the effects into four forces: the positive force exerted by humans on the oasis system (Promotion), the negative force (Pressure), the positive force exerted by nature on the oasis system (Support), and the negative force (Destruction). The research explores the mechanism of interaction among these four positive and negative forces to provide a comprehensive assessment of the stability of oasis habitats (Fig. 1).

In the PPSD (Promotion-Pressure-Support-Destruction) model, the term "Promotion" refers to the positive impact of human socio-economic activities on the oasis habitat. This includes the expansion of oases driven by the construction of water conservancy projects and the enhancement of urban-rural communication facilitated by the development of transportation networks. "Support" denotes the positive support provided by the natural environment to the oasis habitat, specifically referring to the quantity of resources available for the development of oases, such as water, land, and biological resources. "Pressure" represents the negative impact of human socio-economic activities on the oasis habitat, encompassing resource consumption and development burdens, exemplified by water usage and population density. "Destruction" pertains to the negative effects brought about by natural disasters on the oasis habitat within the natural environment. The four forces interpenetrate and mutually constrain each other, ultimately exerting a collective influence on the stability of the oasis habitat. The interplay among these forces is crucial for understanding the dynamics of oasis ecosystems and for developing strategies to maintain their stability and sustainability。

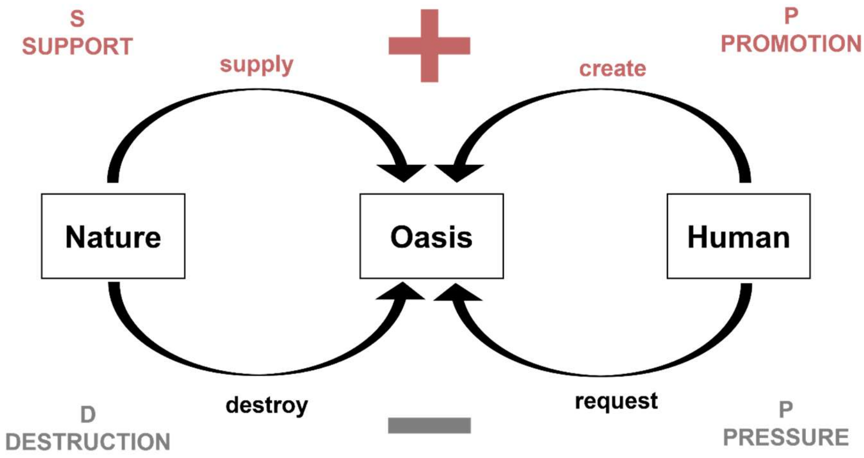

Figure 1. Schematic diagram of PPSD model

During the evolutionary process of the oasis system, the resource pressure caused by human activities has been escalating, exerting significant negative impacts on the system (see Figure 2b). As this pressure continues to mount, if the other forces within the PPSD model do not make corresponding adjustments, the oasis system may lose its original balance and face the risk of collapse (see Fig. 2c). Traditional development models often rely on increasing the intensity of resource exploitation to maintain the stability of the oasis system. Although this approach can enhance the positive influence of nature on the oasis system to some extent, it is imperative to recognize that the capacity of natural resources to provide support is finite.

To achieve long-term stability of the oasis system, a new development pathway must be explored. This new approach aims to enhance the natural support force while also strengthening the supportive role of humans in the oasis system, and reducing the destruction of the natural environment (see Fig. 2d). By doing so, it is possible to alleviate the over-reliance on natural resources and prevent excessive pressure on the natural system. This is not only beneficial for the protection of the ecological environment but also crucial for the sustainable development of the oasis system.

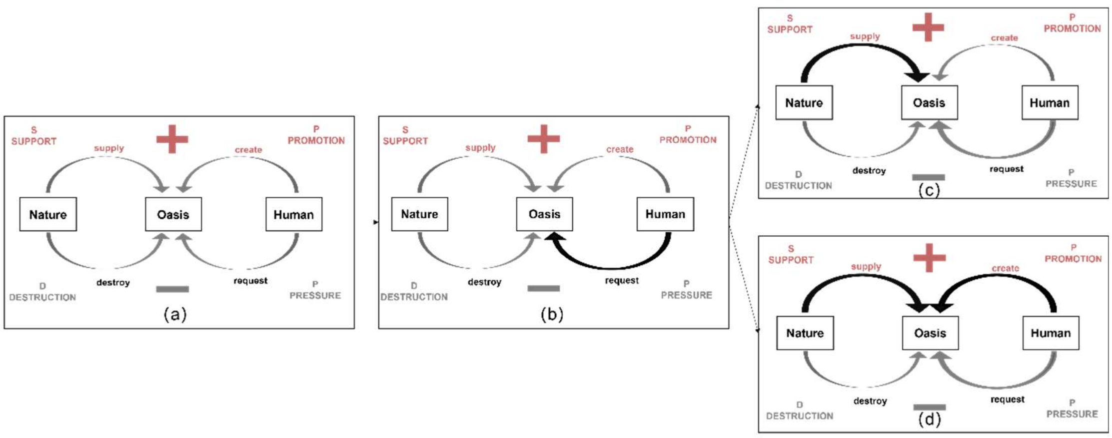

Figure 2. Dynamic development model of PPSD model

2.2. Research Methods

2.2.1. Indicator Reliability Analysis

To minimize the interference of personal subjective judgment in the selection of indicators, we will conduct a reliability analysis of the chosen indicator system. Reliability refers to the consistency of the results obtained when using the indicator system as a measurement tool, which is typically assessed using a reliability coefficient. The higher the reliability coefficient, the more reliable the indicator system is deemed to be. This paper will employ the most commonly used Cronbach's Alpha reliability coefficient method to evaluate the reliability of the oasis stability evaluation indicator system[32]. The calculation formula for Cronbach's Alpha is as follows:

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum_{i=1}^{n}\sigma_i^2}{\sigma_T^2}\right) \tag{1}$$

In the formula: αepresents the reliability coefficient; n is the number of indicator variables; σ_i^2 is the variance of the i th indicator; $\sigma_T^2$is the total variance of the indicator variables. The Cronbach α coefficient reference table indicates that an, $\alpha \geq 0.9$ suggests that the scale is highly reliable; $0.7 \leq \alpha < 0.9$indicates acceptable reliability; $0.5 \leq \alpha < 0.7$suggests that some indicators may need to be revised; α低于 0.5indicates that some indicators in the scale may need to be discarded.

2.2.2. Indicator System Construction

The entropy method primarily takes an objective standpoint, describing the impact of each indicator on the overall evaluation based on the indicator's concentration within the system[33]. The specific calculations are as follows:

1) Data standardization treatment. Since the dimensions of various indicators differ, the range standardization method is used for the standardization treatment of indicator data:

$$r_{ij} = (x_{ij} - x_{imin})/(x_{imax} - x_{imin}) \tag{2}$$

$$r_{ij} = (x_{imax} - x_{ij})/(x_{imax} - x_{imin}) \tag{3}$$

Equations (2) and (3) represent the calculation expressions for positive and negative indicators, respectively. In the formulas, r_{ij} is the standardized value of the j th evaluation indicator for the i th evaluation object; x_{ij} is the original value of the j th evaluation indicator for the i th evaluation object before standardization; x_{imin} and x_{imax} are the minimum and maximum values, respectively, of that indicator for the i th evaluation object.

2) Calculation of Indicator Entropy Values. In an evaluation problem with m evaluated objects and n indicators, the entropy h_j of the j th indicator is calculated as follows:

$$\hbar_j = -k\sum_{j=1}^{m} f_{ij}\ln f_{ij} \tag{4}$$

and, $f_{ij} = r_{ij}/\sum_{j=1}^{m} r_{ij}$； $k = 1/\ln m$

In the formula, f represents the proportion of the i th evaluated object under the j th evaluation indicator, which satisfies$0 \leq f \leq 1$ and $\sum f = 1$. It is stipulated that when $f = 0$, $\ln f = 0$.

3) Defining the entropy. After defining the entropy for the j th indicator, the entropy weight w_j can be obtained：

$$w_j = \left(1 - \hbar_j\right)\Big/\left(n - \sum_{j=1}^{m}\hbar_j\right) \tag{5}$$

3. Xinjiang Aksu Area Wensu County Oasis Steady State Analysis

3.1. Overview of the Study Area

Wensu County (latitude 40°52' to 42°15', longitude 79°28' to 81°30'), under the jurisdiction of the Aksu region of the Xinjiang Uyghur Autonomous Region, is located at the southern foot of Mount Tomur in the middle section of the Tianshan Mountains and on the northwestern edge of the Tarim Basin. It borders Baicheng County and Xinhe County to the east, is adjacent to Aksu City to the south, faces Wushi County across the Tosh River to the west, and is adjacent to the Kyrgyz Republic, the Republic of Kazakhstan, and Zhaosu County of the Ili Kazakh Autonomous Prefecture of Xinjiang to the north. Wensu County is located in the inland arid region of China and has a typical continental climate, with an average annual temperature of 10.10°C, an annual precipitation of 65.4 millimeters, and an average frost-free period of 185 days. There are more than 20 peaks over 6,000 meters within the county, and glaciers above 4,000 meters that do not melt all year round, making it a world-class grand natural solid water reservoir. The oasis is an important carrier for the socio-economic development of Wensu County, mainly distributed in the piedmont river alluvial plains and along the banks of the rivers. The economy developed on this basis is a typical oasis economy[34].

3.2. Data Sources and Indicator Reliability Analysis

3.2.1. Data Sources

The establishment of the indicator system is a core component of the oasis stability evaluation and is a key factor that affects the credibility of the evaluation results. This paper adheres to the basic principles of scientific, systematic, and hierarchical approaches, referencing the "Technical Guidelines for the Evaluation of Resource and Environmental Carrying Capacity and the Suitability of National Land Spatial Development (2019)" published by Ministry of Natural Resources of China as well as existing literature on the indicator system [35–40]. It takes into account the quantifiability and availability of geospatial data to determine the geospatial data (Fig. 3) and specific threshold values (Tab. 1) that can effectively indicate each force.

It takes into account the quantifiability and availability of geospatial data to determine the geospatial data (Fig. 3) and specific threshold values (Tab. 1) that can effectively indicate each force[41]; topographic data is from the SRTM (Shuttle Radar Topography Mission), and vegetation coverage (NDVI - Normalized Difference Vegetation Index) data is from the global MOD13A3 dataset (both jointly measured by NASA and the National Geospatial-Intelligence Agency of the United States); soil erosion data comes from the Chinese Academy of Sciences Resource and Environment Science and Data Center; soil texture data is from the HWSD (Harmonized World Soil Database) global soil dataset[42]; earthquake activity-related data is from the Earthquake Activity Fault Survey Data Center; and evaporation data is from the China 1km monthly potential evapotranspiration dataset (1990-2021)[43].

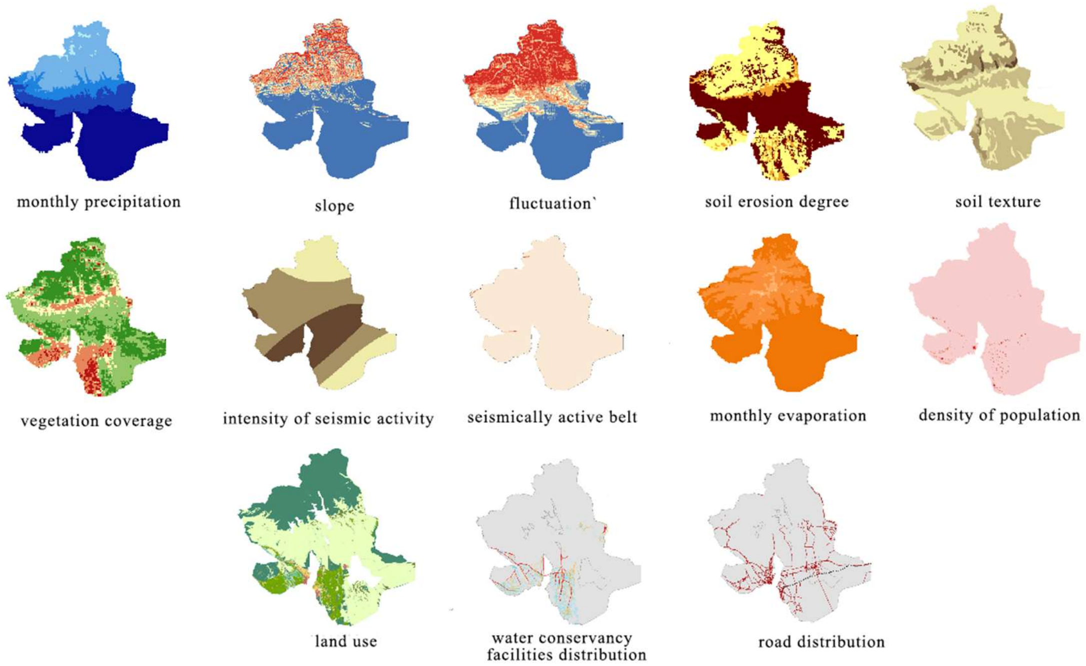

Figure 3. Diagram of each data

Table 1. Thresholds for indicator classification

Indicator data	Indicator code	Thresholds for indicator classification				
		low	Relatively low	General degree	Relatively low	High
Distance from the main canal (m)	K^1_1					
Distance from the secondary canal (m)	K^1_2	Calculating Euclidean distance, divided into five levels based				
Distance from the small canal (m)	K^1_3	on equal distance				
Distance from railway (m)	K^1_4					
Distance from highway (m)	K^1_5					
Population density (/km^2)	K^2_1	205.0	397.5	590.0	957.5	1325.0
Land use	K^2_2	Glacier	Gobi	Forest-grass	Plowland	Towns
Monthly precipitation (mm)	K^3_1、K^{4-1}_1、K^{4-2}_1、K^{4-3}_1	>50	40-50	30-40	20-30	<20
Slope (°)	K^3_2、K^{4-1}_2、K^{4-2}_2、K^{4-3}_2	<3°	3-8°	8-15	15-25	≥25°
Fluctuation (°)	K^3_3、K^{4-1}_3、K^{4-2}_3、K^{4-3}_3	0-20	20-50	50-100	100-300	>300
Soil sediment content (%)	K^3_4、K^{4-1}_4、K^{4-2}_4、K^{4-3}_4	0-35/95-100	35-50/90-95	50-60/85-90	60-70	70-85
Soil erosion degree (%)	K^3_5、K^{4-1}_5、K^{4-2}_5、K^{4-3}_5	low	Relatively low	General degree	Relatively low	High

NDVI (%)	K^{3}_{6}、K^{4-2}_{6}、K^{4-3}_{6}	＞70	50-70	30-50	10-30	＜10
		＞800	600-800	400-600	200-400	＜200
Distance from river (m)	K^{3}_{7}、K^{4-2}_{7}、K^{4-3}_{7}	＞400	300-400	200-300	100-200	＜100
		＞200	150-200	100-150	50-100	＜50
Geological active fault distance (m)	K^{4-1}_{6}	＞500	200-500	100-200	30-100	＜30
Intensity of seismic activity (m/s^2)	K^{4-1}_{7}	≤0.05	0.10	0.15	0.20	≥0.30
Monthly evaporation (mm)	K^{4-3}_{8}	＜50	50-200	200-500	500-1000	＞50

3.2.2. Indicator Validity and Reliability Analysis

In this study, the aforementioned geospatial data were numerically extracted using ArcGIS software. The extracted data were standardized and subjected to reliability and validity analysis (Tab. 2). The results indicate that the Cronbach's α coefficient is 0.739, which suggests that the selected indicator system is acceptable in terms of reliability and can objectively evaluate the stability of the oasis habitat. The KMO (Kaiser-Meyer-Olkin) measure of sampling adequacy is 0.852, indicating that there is a correlation among the variables in the indicator system. Additionally, the results of Bartlett's Test of Sphericity show a significant p-value of less than 0.05, which is statistically significant. This leads to the rejection of the null hypothesis and confirms that there is a correlation among the variables, indicating that the factor analysis is valid and suitable.

Table 2. Reliability and validity analysis

Reliability analysis		Validity analysis			
Cronbach's α	Standard Cronbach's α	KMO	Bartlett's Test of Sphericity		
			Approximate chi-square	df	p
0.739	0.587	0.852	261149.672	136	0.000***

***、**、* representing significance levels of 1%, 5%, and 10%, respectively.

3.2.3. Indicator Weights

Utilizing the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) entropy method, the weights are determined based on the concentration of each indicator within the model, which describes the extent of the indicator's impact on the overall evaluation. This approach attempts to construct a scientific evaluation system of the comprehensive force exerted by nature and humans on the oasis (Tab. 3).

Table 3. Classification of indicator level thresholds

L1	Weight（%）	L2	Weight（%）	L1	Weight（%）	L2	Weight（%）	L3	Weight（%）

		K^1_1	18.033					K^{4-1}_1	66.384
Promotion		K^1_2	21.06					K^{4-1}_2	2.853
K^1	14.107	K^1_3	20.394			Earthq		K^{4-1}_3	5.971
		K^1_4	30.564		19.158	-uake	11.40	K^{4-1}_4	10.288
		K^1_5	9.949			K^{4-1}		K^{4-1}_5	9.297
Pressure		K^2_1	3.545					K^{4-1}_6	0.011
K^2	20.918	K^2_2	96.455					K^{4-1}_7	5.197
		K^3_1	0.395					K^{4-2}_1	0.34
		K^3_2	10.864					K^{4-2}_2	21.20
		K^3_3	22.74	Destru		Flood		K^{4-2}_3	19.97
Supply	45.817	K^3_4	19.573	ction		K^{4-2}	70.11	K^{4-2}_4	25.99
K^3		K^3_5	5.035	K^4				K^{4-2}_5	14.26
		K^3_6	35.242					K^{4-2}_6	7.59
		K^3_7	6.15					K^{4-2}_7	10.66
								K^{4-3}_1	0.102
								K^{4-3}_2	2.8
						Arid		K^{4-3}_3	5.862
						K^{4-3}	18.49	K^{4-3}_4	10.099
								K^{4-3}_5	9.126
								K^{4-3}_6	2.8
								K^{4-3}_7	44.972
								K^{4-3}_8	17.955

3.3. Results

3.3.1. Single Force Analysis

In terms of Promotion, the improvement in technological levels and resource utilization rates in Wensu County has a positive effect on the degeneration of the resource environment. This is primarily reflected in the continuous improvement and expansion of water conservancy and transportation infrastructure. The construction of water conservancy facilities aids in the better utilization of water resources, providing for agricultural irrigation and urban water supply, thereby promoting the progress of agriculture and urbanization. The development of transportation infrastructure enhances the convenience of travel, fostering the development of logistics and tourism both within and outside the region. These measures help to delay the degradation of the resource environment and improve the quality of life within the county.

In terms of Pressure, the socio-economic activities in Wensu County have a relatively high degree of resource consumption and destruction. Both the intensity of land development and the population density are at high levels, indicating that urbanization and agricultural activities are concentrated within the county, with relatively low land use efficiency and significant pressure on the natural environment. The pressure is particularly evident in the southwestern part of the county, which is the oasis area, as these regions are often hotspots for agricultural and urban construction, with high concentrations of human activities and substantial resource consumption.

Regarding Support, the resource potential in Wensu County varies across different areas. A combination of indicators such as slope, fluctuation, NDVI (Normalized Difference Vegetation Index), soil type, soil erosion degree, precipitation, and distance to river channels reflects the diversity of the natural environment. Areas with high support force are mainly concentrated around the oasis and along the rivers. These regions typically have better soil quality and water resources, making them suitable for agricultural production and urban development. However, other areas may face certain limitations in resource utilization due to complex terrain or low precipitation, resulting in lower natural support force.

In terms of Destruction, Wensu County faces risks from various natural disasters. Geological, flood, and drought disasters are the main factors of natural destruction. The southern part of the county, which is relatively flat and has abundant water resources, is less threatened by these disasters and has a lower level of natural destructive force. In contrast, the northern and northeastern parts, which are mountainous and Gobi areas, may be threatened by natural disasters such as avalanches, glacial melting, and mountain mudflows, or face challenges of drought and desertification. In these areas, natural destructive force may manifest as land erosion, depletion of water resources, and damage to the ecosystem.

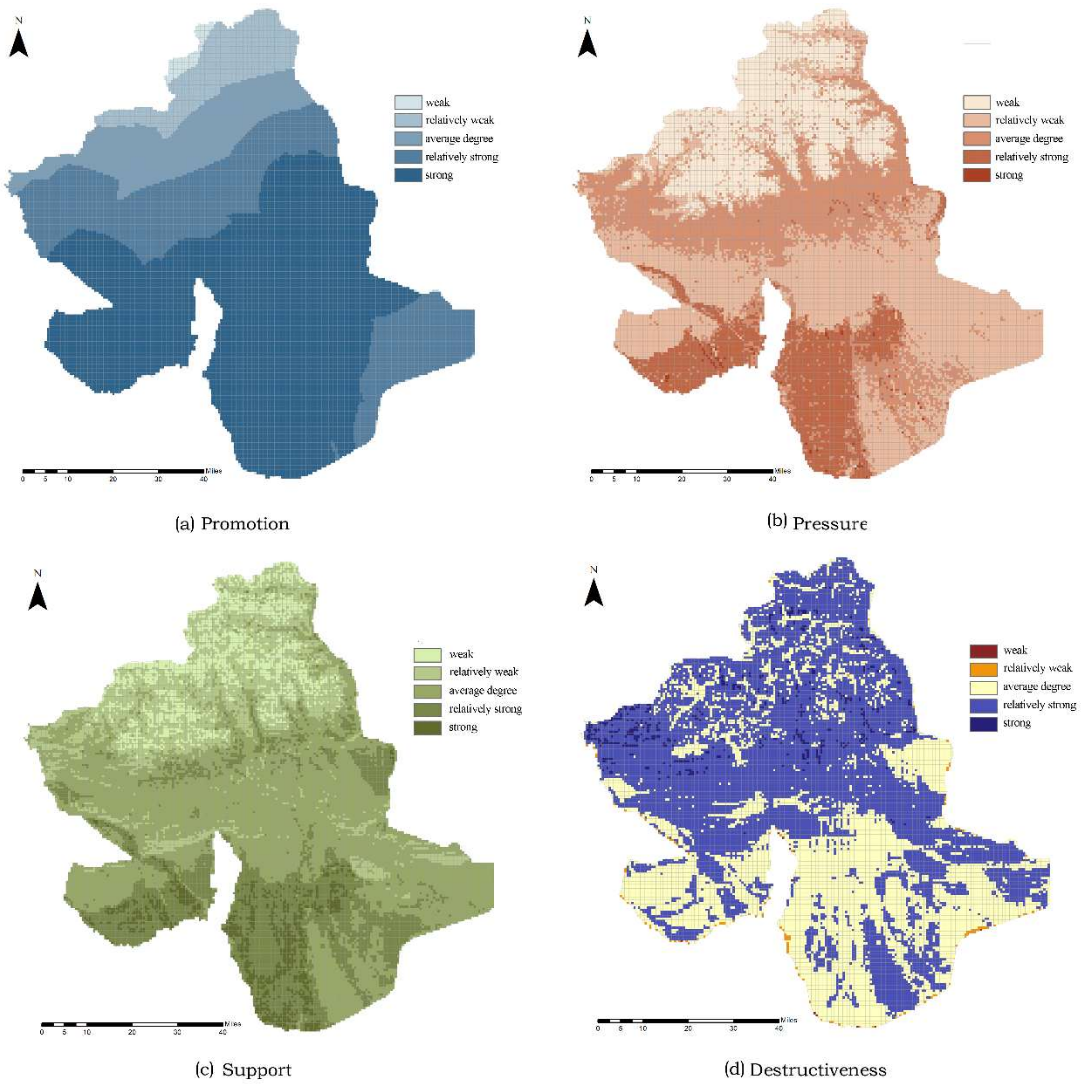

Figure. 4 Spatial evaluation and analysis of each force

3.3.2. Comprehensive Analysis

Based on the PPSD model, the four types of forces were weighted and calculated, resulting in a stability assessment score for the oasis system in Wensu County. The southern oasis and its surrounding areas in Wensu County have shown higher stability scores, depicted in orange-red. This indicates that the region has significant potential and opportunities for ecosystem protection and sustainable development. Particularly, areas that perform well in both the pressure exerted by humans on the oasis and the stability assessment of the oasis system not only maintain good ecological balance but also possess the qualities to become high-quality reserve areas for oasis development. For these areas, it is recommended to further strengthen resource management and ecological protection efforts, aiming to achieve the sustainability of the urban ecosystem and the long-term goals of socio-economic development. This assessment provides solid scientific support for the urban planning and sustainable development strategy of Wensu County, helping decision-makers to more accurately identify priority development areas, optimize resource allocation, and formulate more efficient and environmentally friendly development strategies.

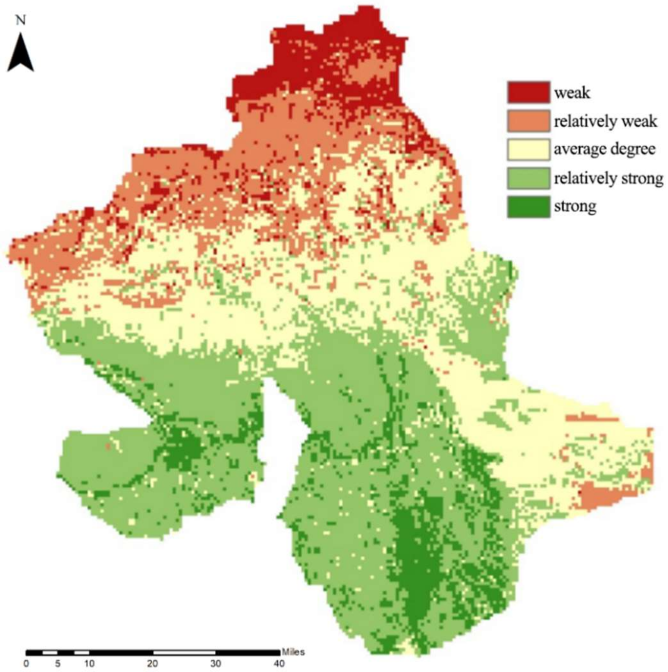

Figure. 5 Spatial stability evaluation analysis based on PPSD model

Through the PPSD model, this study complete a zonal assessment of the stability of the oasis system in Wensu County (Fig. 6). Based on the PPSD model, the zoning map meticulously distinguishes between high and low levels for each type of force, resulting in a total of 16 different stability zones. Compared to a simple stability evaluation analysis map, the stability zoning map more deeply retains the unique attributes of each force, thereby providing a clearer depiction of the causes and influencing factors behind the stability of the oasis system. With this multidimensional analytical framework, it is possible to more accurately identify potential risk areas and areas with improvement potential within the oasis system. This provides a scientific basis for the formulation of targeted management measures and optimization strategies.

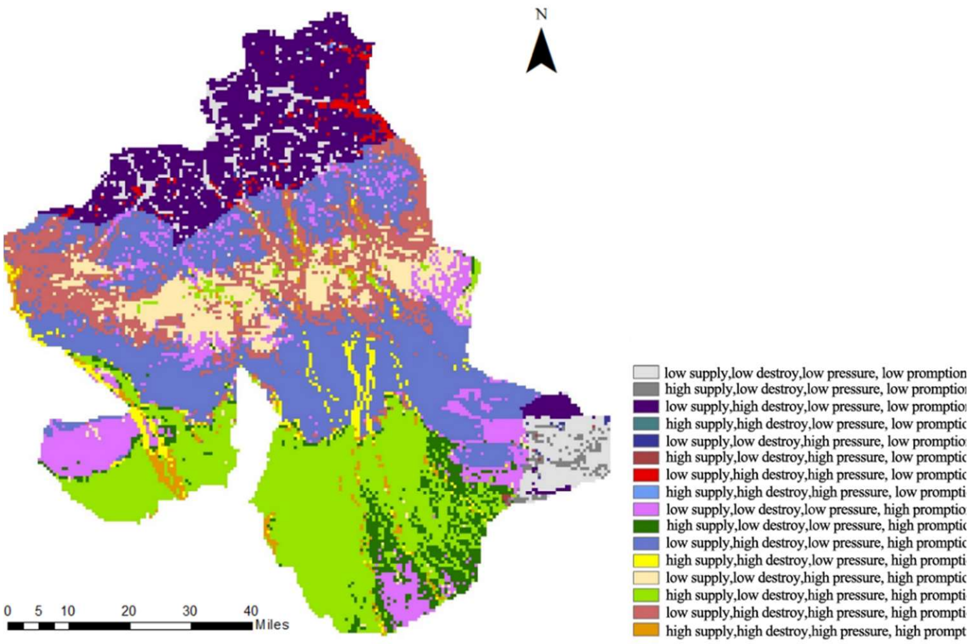

Figure. 6 Spatial stability partition analysis based on PPSD model

4. Planning Application

4.1. County Zoning Planning

In this study, we divided Wensu into distinct zones based on spatial stability zoning, considering the area, connectivity, and current ecological protection and human interference across the sixteen identified region types. (Tab. 4).

Table 4. Partition basis combined with PPSD results

Zone	Definition	Human influence		Natural influence	
		Promotion	Pressure	Support	Destroy
Nature Reserve	An area with relatively little human interference, requiring special protection and restoration due to its rich resources or history of severe natural disasters.	-	-	-	+
Ecological Improvement Area	Important for natural ecological conservation, actively being improved through positive human activities.	+	-	-	+
Ecological Maintenance Area	A balance between natural influences and human impact; the key is to balance human activities with the need for natural conservation.	+	+	-	-

Ecological Restoration Area	Severely damaged by natural disasters and significant human activity. Specific measures are needed to restore ecological functions and enhance resilience to future disasters.	+	+	-	+
Natural Retention Zone	With minimal human and natural forces' impact, it is crucial for preserving the natural state and biodiversity.	-	-	-	-
Natural Development Potential Area	Strong natural positive support with relatively minor disaster destruction, where human positive impact on the ecology is significant, suitable for limited, sustainable artificial development.	+	-	+	-
Artificial Development Potential Area	Favorable natural conditions with minimal disaster impact, improved through proactive human intervention.	+	+	+	-

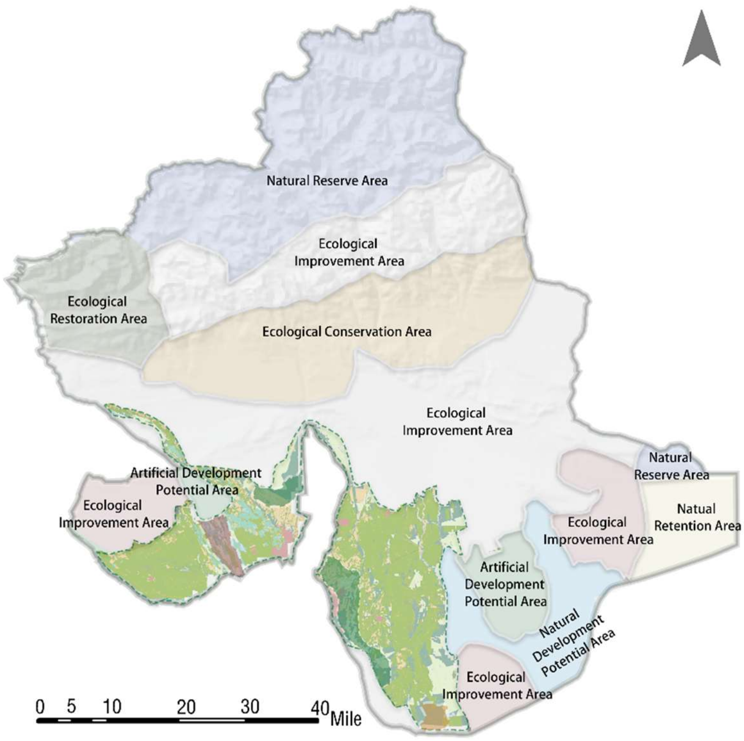

Figure 7. County development and protection zoning proposals of Wensu County

Different zones have different focuses for development and protection: In the nature reserve areas, enforcement of pertinent laws and regulations must be rigorous to limit human activities, with long-term monitoring programs instituted to evaluate and monitor the ecological restoration process. For ecological restoration areas, utilizing native plant species in restoration efforts is essential to bolster the ecosystem's adaptability and resilience, necessitating a sustainable long-term financial and technical support framework. In ecological improvement Areas, the focus is on perpetuating sustainable agricultural practices, enhancing water conservancy infrastructure, and adopting organic farming methods and water-saving irrigation techniques. Within ecological maintenance zones, land use planning and enforcement are critical to curb activities that could upset the ecological balance, with ecological tourism encouraged provided it remains non-intrusive to the natural environment. In natural retention zones, the restriction of all non-essential human activities is paramount in conserving the natural state and preserving biodiversity, with protected areas established to deter illegal poaching and exploitation. Zones earmarked for artificial development should see a push for green technology and sustainable industry proliferation, including renewable energy and ecological tourism, with stringent environmental impact assessments to maintain development within ecological limits. Lastly, areas with potential for natural development should concentrate on the conservation and wise use of natural resources, with community involvement in resource management and protection fostered, and incentives given to ecological agriculture and the sustainable forestry industry to elevate the standard of living for local inhabitants.

4.2. Oasis Development Boundary Delineation

Based on the oasis water-heat balance index, an oasis suitable scale calculation model [44] is used to predict the appropriate size of the oasis under different natural conditions. The specific formula is as follows:

$$A = \frac{W - W_0}{(ET_0 - P)k_p H_0} \tag{6}$$

In the formula, A represents the area of the oasis; W stands for the total amount of water resources available in the basin, which is the total amount of water resources that can be exploited and utilized; W_0 refers to the average annual water volume required for industrial use, domestic use, and river ecological environment within the basin; ET_0 is the reference crop evapotranspiration calculated according to the Penman formula; P indicates the average annual precipitation in the basin; k_p is the comprehensive impact coefficient of the vegetation within the basin, reflecting the influence of the plant's biological characteristics on water demand, taking as 0.82 in this research which is the weighted average of crop coefficients for wheat, corn, and cotton [44]; H_0 is the oasis water-heat balance index, range from 0.50 to 0.75.

Table 5. Prediction of suitable scale of oasis in Wensu County

	2016	2017	2018	2019	2020	2025
W (100 million m^3)	/	38.87	39.49	40.12	41.5	42.3
W_0 (100 million m^3)	1.87	1.86	2.74	2.52	1.39	1.16
P (mm)	87.6	107.1	93.1	93.6	65.7	65.7
ET_0 (mm)	1069.7	1069.7	1069.7	1069.7	1069.7	1069.7
Existing scale（km^2）	3975.99	4242.03	4195.67	4177.01	4156.07	/
Minimum suitable size (km^2)	2736.6	3137.9	3071.3	3143.9	3260.6	3344.3
Maximum suitable size (km^2)	4104.9	4706.9	4606.9	4715.9	4890.9	5016.5

According to Table 5, the suitable development scale for the oasis in Wensu County in 2025 is between 3344.3 and 5016.5 km². This means there is a potential for expansion of up to 860.43 km² based on the year 2020.

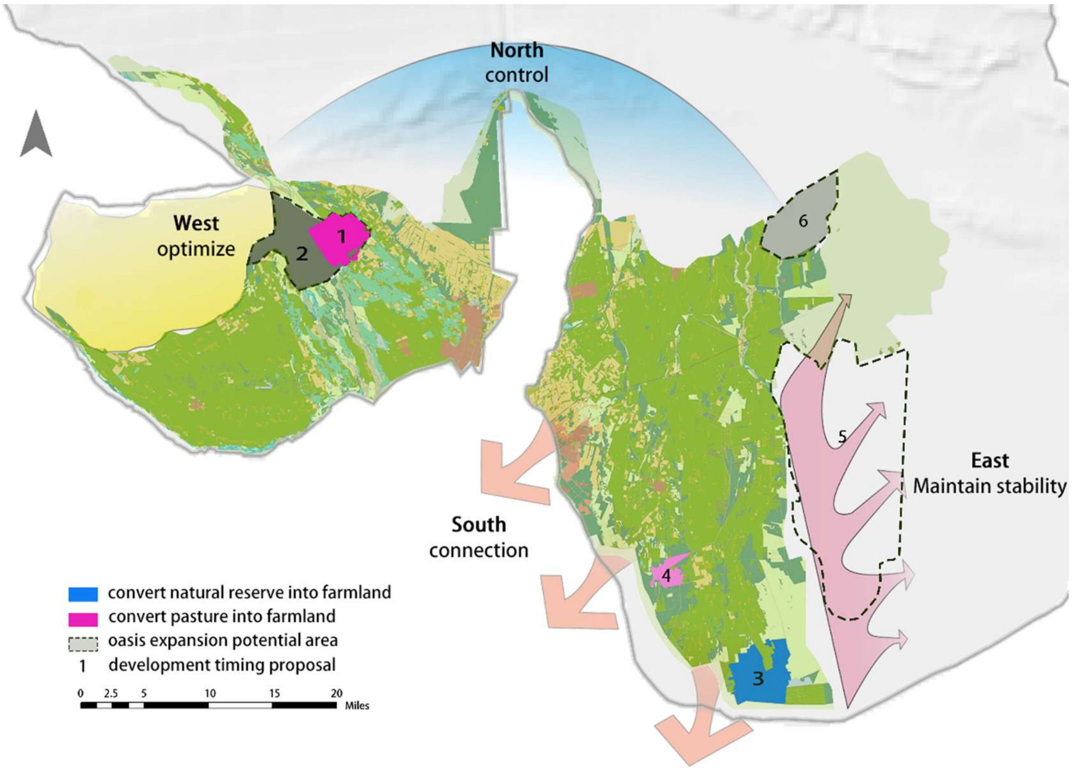

Figure. 8 "High potential Area" for oasis development in Wensu County

Based on the analysis results of oasis stability evaluation and spatial zoning, the study identified six "high potential areas" with high stability and development potential. Accordingly, the following principles for oasis stability and sustainable use management are proposed: "Control the North, Stabilize the East, Connect the South, and Optimize the West." The focus in the west is to optimize the area west of the Kumala River, leveraging the region's excellent water resources and land stability to improve land use efficiency. In the north, where development speed and scale should be controlled, consideration is given to the ecological sensitivity of the Haman Tala Mountains and the importance of soil and water conservation to avoid adverse environmental impacts from overexpansion. The eastern region, which is primarily designated as ecological public welfare forest, should strengthen its connection with the Qingnian Tuan Town. Utilizing the development potential and resources of this area, a joint effort should be made for the protection and ecological restoration of the original natural vegetation in the eastern region. The south should effectively connect with the Aksu urban area to enhance the interaction between the oasis and the city, promoting resource sharing and economic integration, and enhancing the overall competitiveness of the oasis.

Combining the results of the oasis suitability scale, the following management measures are recommended for the six "high potential areas" in terms of the development sequence: Prioritize the optimization of the west, relying on the favorable stability conditions of the oasis in this area, and implement the land use conversion for Area 1, while planning Area 2 as the key area for future expansion. After the optimization of the western region is completed, gradually expand towards the east and south to form a linked development pattern between the oasis and the city. At the same time, plan for the long-term development of the north and west, and formulate long-term land use planning and expansion strategies based on their natural conditions, artificial conditions, and relationship with the existing oasis. For example, Areas 3 and 4, which have excellent natural and artificial conditions, could consider adjusting the land use type to arable land to enhance the stability of the oasis habitat. Areas 5 and 6 have certain potential for oasis expansion, but considering the potential for water resource allocation, stability, and the current ecological public welfare forest attribute of the land, it is recommended in actual planning to focus on "stability," reflecting the concept of ecological priority.

5. Conclusion and Discussion

This study evaluates the stability of the oasis in Wensu County, Xinjiang, by constructing the PPSD (Promotion-Pressure-Support-Destructiveness) model, taking into account both natural environmental factors and human activities that affect oasis stability. The findings reveal that the peripheral areas of the Wensu County oasis generally have high stability, with particularly notable regions on the northwest side of the western oasis, the southern part of the eastern oasis, and the eastern and northern sides. Based on different combinations of forces, Wensu County is divided into eight protection and development zones, each with corresponding planning or conservation recommendations. The study proposes development and protection strategies focusing on optimizing the west, controlling the north, stabilizing the east, and connecting the south, providing sequential suggestions for spatial planning, land use, and ecological protection and restoration to promote sustainable development of the oasis and harmonious coexistence between humans and nature.

Against the backdrop of the establishment of the national spatial planning system, future research can delve into the following directions to promote sustainable development and ecological balance of the oasis [45－47]:

(1) Oasis Utilization and Ecological Restoration: In-depth exploration of the interaction between human activities and the natural environment, especially the role of human creative factors in enhancing the efficiency of natural resource use in oases and strengthening their resistance to natural disasters. This will help develop ecological restoration strategies, optimize human utilization of oases, and protect and restore their ecological functions.

(2) Research Support for Resource Conservation in National Spatial Planning: In response to the limitations in data acquisition, efforts should be made to develop new data collection and analysis methods to support more refined resource assessment and planning. This will provide a quantitative, vectorized scientific basis for national spatial planning to ensure the rational allocation and protection of resources.

(3) Regional Environmental Resources and Oasis Protection: Assess the impact of regional environmental resources on oasis protection from a broader spatial range and a more macro perspective. Explore the stability of oases under different geographical and climatic conditions and develop cross-regional ecological management and protection strategies to achieve a wider ecological balance and long-term stability of oasis systems.

(4) Oasis Resilience Research in the Context of Climate Change: Given the potential impact of climate change on oasis stability, focus on assessing the effects of climate change on oasis ecosystems and explore methods to enhance the resilience of oasis systems. This may include studying the impact of climate change on water resources, land use, and biodiversity, as well as developing adaptive management measures to enhance the adaptability of oases to climate change.

Through these research directions, more comprehensive and in-depth scientific support can be provided for the planning, management, and protection of oases, promoting the health and sustainable development of oasis ecosystems.

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