

Review

Oasification in Arid and Semi-Arid Regions of China: New Changes and Re-Examination

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Abstract: The “counter-trend” of oasification in China’s arid and semi-arid regions has attracted widespread attention against the backdrop of the rising global desertification risk, which endangers ecological safety and food security. This paper selects the pertinent literature from the CNKI and the WoS core collection databases and then uses bibliometric methods to comb the current status, key contents, and cutting-edge trends of oasification research. The following conclusions are drawn: (1) Compared to desertification research, research on oasification has not been sufficient and the understanding of oasification has not been raised to the same level of importance as desertification; (2) From the perspective of the literature, the oasification research hotspots have gone through four stages: “spatial and temporal evolution, ecological effects, driving mechanisms and sustainable development paths”; (3) Current research on oasification is mainly focused on the evolution of landscape dynamics, sustainable development, and ecological conservation. Research outlooks are as follows: (1) From the perspective of system theory, we construct a theoretical framework of “man and nature” harmonious community, and systematically study the alternating evolution process of “desert–oasis” in arid and semi-arid regions, and its effects; (2) The synergistic factors, development mechanism and preferred path of oasification sustainable development should be some of the key contents of future research; (3) Oasification management in arid and semi-arid regions is not the opposite of desertification management, and research on the oasification governance system, governance content and governance mechanism is necessary.

Keywords: desertification; oasification; sustainable development; bibliometric



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1. Introduction

Due to the compounding effects of climate change and human activity since the 21st century, the risk of global desertification has risen significantly with droughts and dust storms wreaking havoc. Desertification impacted more than 100 countries and regions, and 1.5 billion people in the desert belt, directly jeopardizing global food protection and ecological safety, leading to hunger, poverty, and forced migration, inducing geopolitical conflicts, hindering development, and thus posing a threat to international peace and security [1]. Accordingly, the 13th Conference of the Parties to the United Nations Convention to Combat Desertification (UNCCD) in 2017 proposed “Working Together to Combat Desertification for the Benefit of Humanity”, appealing for countries around the world to actively cooperate and jointly address the risk of desertification. China is one of the countries with the largest desert areas in the world, and desertification has always been the focus of environmental management in the arid and semi-arid regions of China. Since the 1970s, China has launched the “Three Norths” protective forest system construction, Beijing–Tianjin wind and sand source control, “returning farmland to the forest”, and other major national ecological restoration projects. With the rapid promotion of a series of ecological restoration actions, the trend of desertification in arid and semi-arid areas has been curbed to a certain extent, and the results of desertification control in Shaanxi, Ningxia,

Gansu, Inner Mongolia, Xinjiang, and other provinces (autonomous regions) have been remarkable [2]. The land in arid and semi-arid regions has changed from yellow to green, the index of “land degradation restoration” has been significantly improved, and local areas have demonstrated the evolution of oasisification [3,4]. Against the background of increasing global desertification in arid and semi-arid regions, the phenomenon of the “counter-trend” of oasisification in China’s arid and semi-arid regions is an frequently issue of discussion in the scientific community today. The impact of oasisification, in sum, on ecosystems has both pros and cons. Oasis ecosystems mitigate wind erosion, improve soil fertility, and boost the growth of plants, which may promote desertification control and enhance the ecological environment [5,6]. However, oasis ecosystems cause overexploitation of land, exacerbating soil salinity, alkalization and desiccation in deep soil layers. The high-density use of water resources and the sinking of the water table lead to water scarcity, which may weaken the long-term stability of oasis ecosystems [7,8]. The studies from Deng et al. (2015) and Feng et al. (2016) demonstrate that oases exist because of water, and the carrying capacity of water resources is critical to the existence of oases [9,10]. Oasisification, to some extent, is conducive to an ecological environment; however, a disorderly expansion of oasisification will overly exploit water resources and lead to the decline of oasis stability, which eventually increase the risk of desertification in arid areas and the local ecological balance [11]. Thus, knowledge of the long-term effects of oasisification should be key to sustainability in a water-limited environment, for example, the balance between the pros and cons of oasis ecosystems; moreover, knowledge of the driving mechanisms, and evolution laws of the oasisification process could provide theoretical and technical support for the sustainability in arid and semi-arid areas.

In recent years, the research literature on oasisification has been growing rapidly. Scholars have discussed the influencing factors, results, and boundary conditions of oasisification in different regional contexts, and have produced rich research results. However, the existing studies still lack an in-depth understanding and examination of the new change of oasisification and the underlying mechanism. Therefore, to further expand and deepen the research in this field, it is necessary to systematically organize and review the existing literature. Tracing the representative literature reviews on desertification and oasis in the past 20 years, we found that a few existing relevant review studies have conducted some work in this area, but there are still two shortcomings: first, most of the articles have reviewed the relevant studies on desertification in detail [12–14], and also explored the relationship between desertification and oasisification [15]. However, a few reviews have focused exclusively on the study of oasisification [16–18], which cannot reflect the “counter-trend” phenomenon of oasisification that has been emerging in recent years. Second, the current research reviews in this area mainly use traditional qualitative methods, and some of them only focus on a particular research perspective, such as the general development of desertification research assessment indicator systems, early warning methods, and cost estimates [19–21]. The few quantitative review studies, in their empirical analysis of the literature characteristics and key hotspots, only use literature data from a single database, CNKI or WoS [22,23], which cannot reflect the whole picture of oasisification research in the Chinese context and largely weaken the guiding role of the existing studies. Therefore, it is necessary to summarize and review the existing studies again and look ahead to potential research directions.

This paper is organized as follows: We first present the research area, research sample, and research method in Section 2. Then, we use the bibliometric method to discuss the time distribution and discipline distribution of oasisification research, and the development trend and frontier themes of research hotspots in Section 3. We adopt an inductive method to discuss the main views and contents of oasisification research and construct an overall framework of oasisification research under sustainable development in Section 4. We then present the discussion in Section 5. Finally, a summary and outlook are given in Section 6, in which we highlight the potential importance of oasisification and recommend the main points of oasisification research in the future.

2. Research Design

2.1. Research Area

Arid zones, which account for 41% of the global land area, are among the most vulnerable areas in terms of ecosystems and water resources systems, and are also the most sensitive to climate change responses, supporting 38% of the world's population and spreading over 50 countries on all continents [24]. A reasonable delineation of arid zone distribution is of great significance for an in-depth understanding and accurate grasp of the climatic characteristics of arid zones. According to the classification criteria defined by the United Nations Environment Programme (UNEP), the aridity index is used to classify arid areas into four types: extremely arid, arid, semi-arid, and semi-humid semi-arid areas, which account for 7.5%, 13.0%, 15% and 6.2% of the global land area, respectively. It can be seen that arid and semi-arid areas account for the highest proportion, so this paper is mainly based on these two parts. Qader et al. (2021) mapped arid and semi-arid zones accordingly [25], as shown in the colored area of Figure 1, where it was estimated that the area of arid zones is about 28 million km² and the area of semi-arid zones is about 46 million km². For the specific regional distribution of arid and semi-arid regions, some scholars divided the globe into nine arid and semi-arid regions, including North Africa, Southwest Asia, Middle East Asia, Sahel, Horn of Africa, South Africa, Australia, Southwest USA, and Patagonia [26]. However, some scholars thought that the three arid regions of North Africa, Sahel, and the Horn of Africa were too finely divided, so the globe was divided into eight arid regions: Midwest USA, South America, North Africa, Southern Africa, Southwest Asia, Central Asia, Central Mongolia and the arid semi-arid zone of Australia [27]. The combination of population growth, poverty, unsustainable land use, and urbanization will increase the risk of desertification and increase the number of desertified areas around the world [28]. The global desertification area starts from the Sahara in northern Africa and passes through the Arabian Peninsula in southwest Asia, Iran, northern India, Central Asia to northwest China and Mongolia, forming a giant desert belt stretching 13,000 km, accounting for about 67% of the global desert area. Due to its wide scope and impact, desertification has become one of the world's most serious environmental problems and will remain the core problem facing arid regions in the future [29].

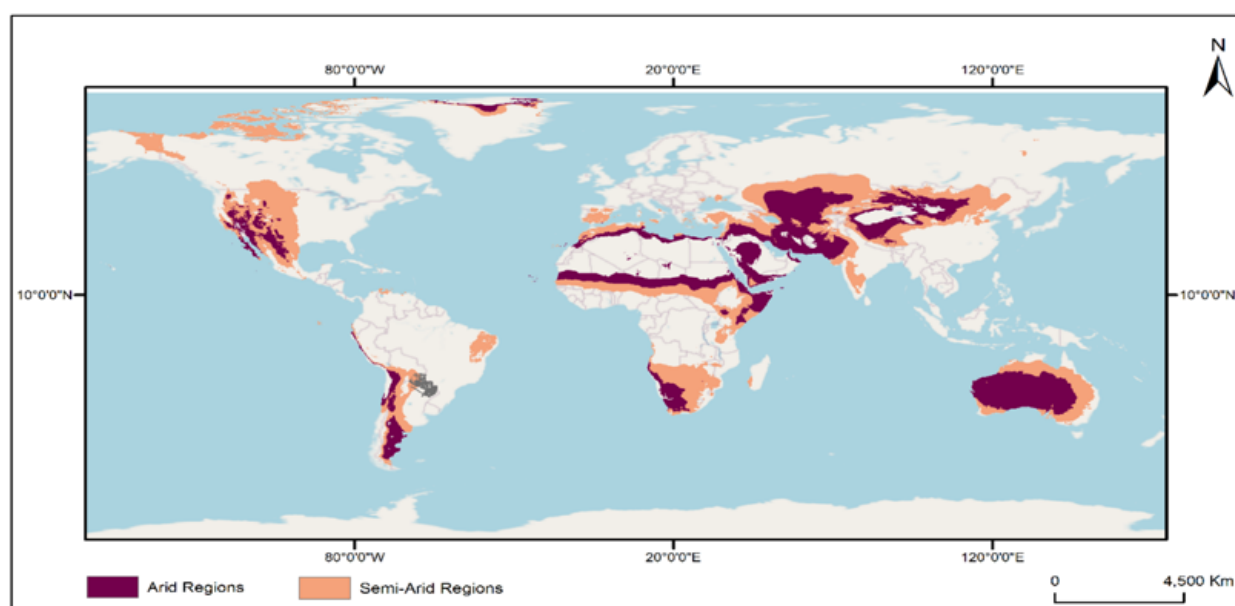


Figure 1. Global distribution of arid and semi-arid (ASA) regions.

China is one of the world's leading arid countries, with 6.6 million square kilometers of drylands supporting about 580 million people, which are at risk of desertification, as well as one of the world's largest areas of desertification, most affected populations, and most endangered by wind and sand. China's arid and semi-arid areas are mainly distributed in northwest and north China, and 83% of the arid and semi-arid areas are concentrated in northwest China again, including five provinces and regions in Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, and the central and western regions of Inner Mongolia [24]. Drylands are characterized by a scarcity of water, which affects both natural and managed ecosystems and constrains the production of livestock, as well as crops, wood, forage, and other plants, and affects the delivery of environmental services. It is also this characteristic that makes human factors an important driver of dryland mismanagement, including the disruption of pastoralist mobility, cultivation of fragile dryland soils, etc. Specifically, with the development of social productivity, rapid increase in population, and the influence of socio-economic interest drive, the intensity of human activities has been increasing, over-cultivation is leading to unreasonable land use, overload grazing, wind and solar energy development and construction, excessive use of water resources and other behavioral activities, which directly affect the expansion of dryland desertification. Correspondingly, desertification expansion affects the change of ecological and environmental conditions (precipitation decreases, vegetation destruction, etc.), resulting in the decrease in available land resources, the death of livestock, the abandonment of arable land, the decrease in productivity year by year, the decrease in arable land area and year-end stock, which hinders people's living standard and further accelerates the development of dryland desertification and the deterioration of the environment. At present, desertification control in drylands has also received much attention from the Chinese and even the international academic community, while many research results have been produced and have favorably promoted environmental management. Oasification research has emerged along with desertification control; oases and oasification are effective ways to partially reverse desertification under the premise of ensuring water sources [18]. Although the research on oasification has received increasing attention in recent years, it still needs further exploration in arid and semi-arid regions. Therefore, China has been chosen as a research case, and the academic results of Chinese and international scholars on the oasification of China's arid and semi-arid regions have been selected as the data source to reveal the research trends, hotspots, and frontiers of oasification in the arid and semi-arid regions of China from the bibliometric perspective, and to provide information and intelligence support for researchers, management decision-makers and land users worldwide.

2.2. Research Sample

This paper focuses on the study of oasification in the Chinese context. The research sample includes oasification studies published in important Chinese journals and studies conducted in international journals with China as a case study, and its findings are helpful in guiding the practice of oasification in the arid and semi-arid regions of China on the one hand, and to provide a reference for the international theory and practice of oasification on the other hand. To fully analyze the current research status and frequently discussed issues in the field of oasification in the arid and semi-arid regions of China, the sample literature was collected and selected using the following steps: First, the CNKI database and the Web of Science (WoS) database were used as data sources, and the advanced search function was used to collect the relevant Chinese and foreign literature in this field, respectively; meanwhile, to ensure the research quality of the selected literature as much as possible, the SSCI and SCI databases in the core collection of WoS were used as sources for the foreign literature, and the CSSCI and CSCD databases in the CNKI were used as sources for the Chinese literature, whose journal sources are respected and representative. Second, this paper selected 2001–2021 as the time span of the literature selection, set the subject search terms as TS = (oasis and dynamic) or (oasification or oasisization) and (China or Chinese), and selected the literature type as "article". The data were downloaded on 3 May 2022,

and 589 Chinese and 483 foreign language documents were initially retrieved. Third, to ensure the accuracy of the data and improve the validity of the analysis, this paper read the titles, keywords, and abstracts of the initially retrieved documents one by one, and finally, identified 342 valid Chinese documents and 462 valid foreign documents after manually eliminating the literature information that did not match the topics and affected the measurement results.

2.3. Research Method

The bibliometric approach is to study the quantitative characteristics of the literature through mathematical and statistical methods, and then evaluate and predict the current status and development trend of the discipline. Commonly used tools for bibliometric visual analysis include CiteSpace, VOSviewer, Gephi, R language, etc. In this paper, CiteSpace software was used to visualize and analyze the literature on oasisification. On the one hand, the basic situation of the field was statistically analyzed, and the temporal trend and disciplinary span of the research literature in the field of oasisification were observed from the perspective of the distribution of time of publication and discipline. On the other hand, the distribution and cooperation of country–institution–author in the field were identified by mapping the cooperation, and the trend of research hotspots and frontier themes were grasped by mapping the co-occurrence and emergence of keywords. In the Citespace visualization analysis, this study followed the following steps: (1) The data were de-duplicated before being imported into the CiteSpace software; (2) For software processing, the time interval was set to 1 and the threshold value was selected as Top 10; (3) Research analysis functions were selected for different research purposes, and country–institution–author distribution and collaboration analysis, keyword co-occurrence, and emergence analysis were performed in turn; (4) Based on the mapping drawn, the visualized research results were interpreted. Based on this, the hotspots and frontiers of the retrieved research were systematically elaborated using induction and collation to explore theoretical research points for further improvement and refinement in the future.

3. Research Results

3.1. Temporal Distribution of the Literature

The number of annual publications is an important indicator of the development trend of oasisification research. As shown in Figure 2, there are some discrepancies in the attention to the theme of oasisification between China and foreign countries, the number of articles published in China shows an overall M-shaped curve, whereas the number of articles published in foreign countries shows a fluctuating upward trend. From 2001 to 2008, academics paid little attention to oasisification research because it was still in its initial stages. Beginning in 2009, it gradually came to the attention of researchers. In the number of articles published in Chinese journals, 2009 marked a breaking point; the years from 2009 to 2013 saw a relatively high level of attention from the Chinese academic community, and the years from 2013 to 2018 saw a fluctuating downward, reflecting the decreasing attention the academic community paid to the study of oasisification. Moreover, the number of articles published in foreign journals has seen a fluctuating rise since 2009, indicating that the international academic community is paying more attention to this field of research. In general, oasisification research has received great attention in both Chinese and foreign journals in the last five years.

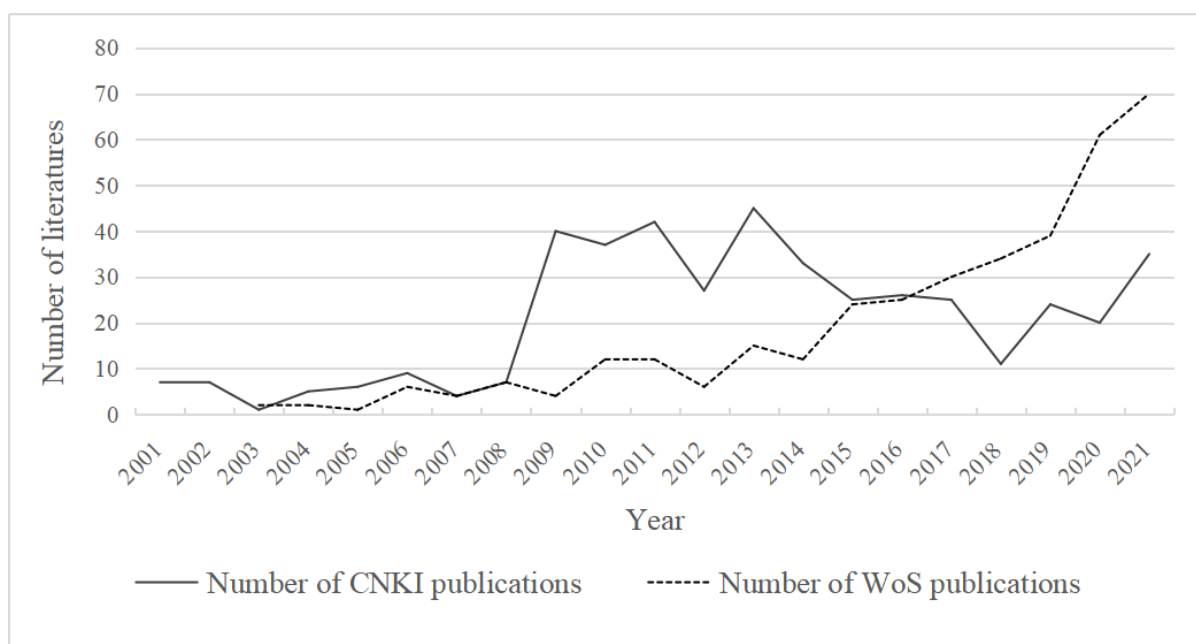


Figure 2. Annual distribution trend of oasisification research literature (2001–2021).

3.2. Discipline Distribution of the Literature

Table 1 shows the distribution and percentage of the top 10 disciplines in the CNKI and WoS databases, from which it is found that oasisification research penetrates most fields related to environmental issues; most of the literature belongs to cross-disciplinary research, and the top three disciplines in both databases are the same. The highest percentage of papers published is in the discipline of Environmental Sciences, accounting for more than 1/3 of the entire discipline distribution. The subsequent research fields not only include natural disciplines such as hydrology, soil, and ecology but also involve humanities and socio-economic disciplines, indicating that oasisification is a relatively complex process and requires a cross-disciplinary perspective for oasisification research. In addition, the span of disciplines in this field is increasing year by year, and interdisciplinary research has become the trend and characteristic of research in this field.

Table 1. The discipline distribution of oasisification research literature since 2001.

Ranking	Subject Classification of CNKI	Subject Classification of WoS
1	Environmental Science and Resource Utilization (33.67%)	Environmental Sciences (40.40%)
2	Biology (8.31%)	Ecology (18.14%)
3	Physical Geography and Mapping (8.14%)	Geosciences Multidisciplinary (17.50%)
4	Agricultural Basic Science (7.98%)	Soil Science (12.20%)
5	Agronomy (6.88%)	Water Resources (10.79%)
6	Agricultural Economy (5.54%)	Geography Physical (6.25%)
7	Animal Husbandry and Animal Medicine (3.95%)	Meteorology Atmospheric Sciences (6.07%)
8	Meteorology (3.44%)	Remote Sensing (5.01%)
9	Forestry (2.94%)	Plant Sciences (4.73%)
10	Automated Technique (2.35%)	Multidisciplinary Sciences (4.55%)

3.3. Research Hotspots and Development Trends

Research hotspots are topics that appear more frequently in a certain period, and keywords are the highly condensed content of the research literature and the essence of research topics, so the statistics and analysis of keywords are particularly important to

enable us to quickly grasp the research trends and research hotspots in a certain field. In the following section, the visualization figures generated by two perspectives of keyword co-occurrence and emergence show the current research status and future research directions.

3.3.1. Analysis of Research Hotspots

The keyword co-occurrence analysis can observe the distribution of high-frequency keywords in the field. From the keyword co-occurrence network mapping of oasisification research in Figure 3, the high-frequency keywords of oasisification research in the CNKI database and WoS core collection database roughly include an oasis, land use, dynamics, desertification, arid region, landscape, human activity, soil salinization, etc. These high-frequency keywords show the focus of oasisification research and need further attention.

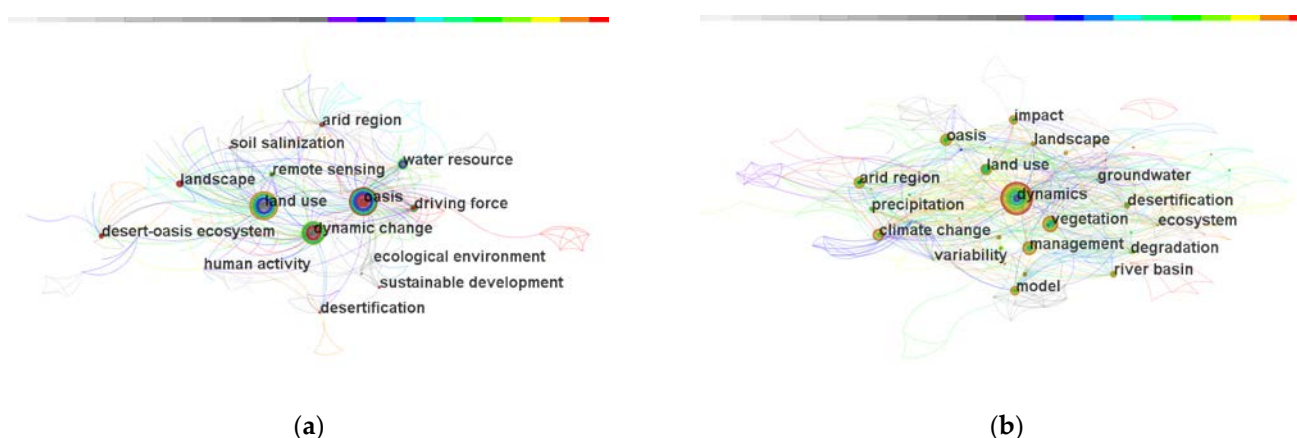


Figure 3. The co-appearance network of oasisification research keywords (2001–2021). (a) CNKI database; (b) WoS database.

3.3.2. Analysis of Research Frontiers

It can be observed in the emergent keyword analysis that the trend of word frequency changes in the field. The more burst nodes a cluster contains, the more active the field is. Not only can the emergent word network mapping by CiteSpace visualize the topics that have received attention in early and recent years, but also the keywords with the highest emergent intensity and the longest emergent time, where the highest emergent intensity represents the most attention in a certain period and the longest emergent time represents a long period of attention. This study analyzes the keyword emergence of the oasisification research literature in the CNKI database and WoS core collection database, specifically in three dimensions of emergence intensity, emergence start time, and emergence duration (see Figure 4). In the dimension of emergence intensity, the top three emergent intensities in the Chinese literature are sustainable development, oasis, and landscape, while the top three emergent intensities in the foreign literature are environment, climate change, and sustainability. These key technical areas represent several major aspects of the subject of oasisification, and as a result, they have received widespread attention and become highly influential research frontiers. In the dimension of emergence time, on the one hand, from the persistence period, the keywords “ecological environment” and “desert–oasis ecosystem” have the longest persistence period in the Chinese literature (7 years), whereas the keyword “remote sensing” has a persistence period of 6 years in the foreign literature, indicating that this is the focus of attention all the time. On the other hand, from the beginning to the end of the emergence, the Chinese literature paid attention to ecological and environmental research in the field of oasisification in 2005, while the foreign literature only paid attention to environmental issues in 2010. In the last two years, the dynamic evolution of desert–oasis ecosystems has been a topic of interest in Chinese journals, and sustainability and conservation are two major themes of interest in foreign journals. These technical branches are our future research directions and targets, especially the key scientific issues of the

imbalance of ecosystems, warming and humidification caused by extreme climate change, and the imbalance between ecological protection and economic development.

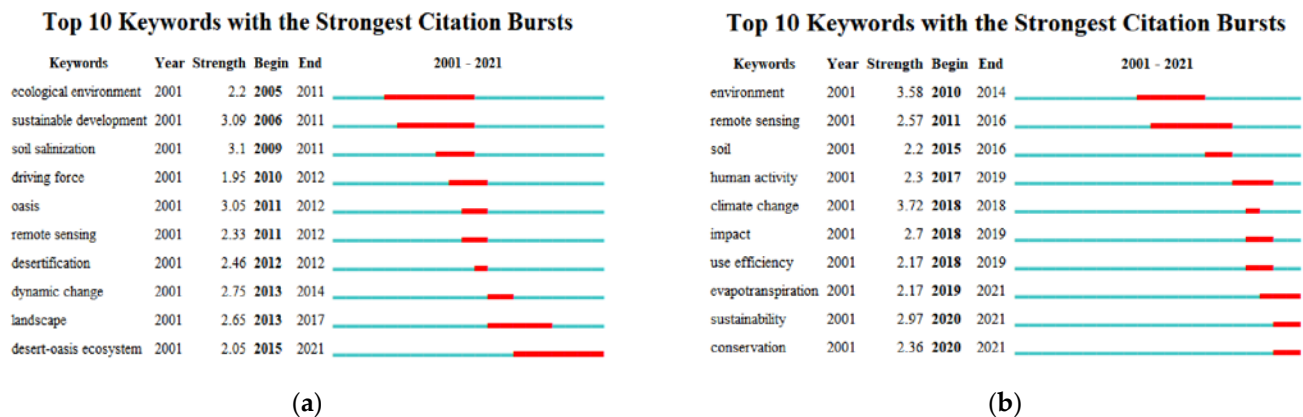


Figure 4. The frontier burst words of oasisification research (2001–2021). (a) CNKI database; (b) WoS database.

The co-occurrence and emergence of the keywords show that the research is primarily focused on China's arid regions; Xinjiang is the region that has been studied the most in this regard. The oasis ecological protection and sustainable development are the original purposes of academic research. Climate change and human activities are the dual drivers affecting oasisification. The dynamic transformation of desertification and oasisification and the landscape pattern are the external manifestations affecting the ecological environment; land use/cover change and water resources are the internal operation mechanism.

4. Main Contents and Views

Figures 3 and 4 present the high-frequency words and dynamic development trend of the oasisification research themes in arid regions. In terms of the distribution of research themes, the existing research focuses more on the spatial and temporal evolution, ecological effects, driving factors, and sustainable development paths of the oasisification process. Based on the high-frequency keywords and a high number of citations, the representative literature of the four major themes is extracted in Table 2. This section then discusses each of the existing research themes to clarify the research lineage and to provide a literature basis for the construction of a research framework on oasisification in arid and semi-arid regions.

Table 2. Research themes and related literature.

Research Theme	Keywords	Representative Literature	
		Title	Author (Year)
Spatial-Temporal Evolution	Landscape pattern	Preliminary analysis on the oasis stability at the landscape level in the arid regions.	Luo, G.P.; Zhou, C.H.; Chen, X. (2004) [30]
	Land use/cover change	Quantifying the impacts of land use/land cover change on groundwater depletion in Northwestern China—a case study of the Dunhuang oasis.	Zhang, X.F.; Zhang, L.H.; He, C.S.; Li, J.L.; Jiang, Y.W.; Ma, L.B. (2014) [31]

Table 2. Cont.

Research Theme	Keywords	Representative Literature	
		Title	Author (Year)
Ecological effects	Environmental effect	Oases, as well as their sustainable development, and constructions in China.	Shen, Y.C.; Wang, J.W.; Wu, G.H. (2002) [32]
	Ecological conservation	A review of the research on oasisization and its environmental effect in the northwest arid regions of China.	Yang, Y.T.; Yang, Y.; Wu, Z.Y. (2015) [33]
	Climate change	The geographical features and climatic effects of oasis.	Zhang, Q.; Hu, Y.Q. (2002) [34]
Driving Factor	Human activity	Human driving forces of oasis expansion in northwestern China during the last decade—a case study of the Heihe River Basin.	Zhou, D.Y.; Wang, X.J.; Shi, M.J. (2017) [35]
	Driving force	The constraints and driving forces of oasis development in arid region—a case study of the Hexi Corridor in Northwest China.	Bie, Q.; Xie, Y. (2020) [36]
Sustainable Development Path	Sustainable development	Theory and practice of oasis ecological economic sustainable development.	Li, W.M. (2003) [37]
	Suitable scale	Analysis of oasis evolution and suitable development scale for arid regions—a case study of the Tarim River Basin.	Chen, Y.N.; Chen, Z.S. (2013) [38]

4.1. Study on Driving Mechanism of Oasisification

It is widely accepted in academia that natural factors, such as precipitation and evapotranspiration due to climate change and socioeconomic factors such as population growth, economic demand, water use, technological advancements, and land use policies, drive the expansion and contraction of oases [39]. Through the circulation and transformation of material flow, energy flow, and information flow between the ecosystem and economic system, Man and nature make the structure and function of the oasis ecological-economic system evolve dynamically, which is the internal and external driving force affecting the stability of the oasis [40,41]. Climate change is a natural trigger for the dynamic evolution of desert–oasis, and in this context, human factors, such as dramatic population growth, economic development, technological progress, and institutional changes, work together to accelerate the expansion of artificial oases and the direction and extent of oasis evolution [42]. Compared to climate change, human activities are the main cause of and play an important role in the evolution of oasis ecological-economic systems, with a dual impact on eco-economic development [43]. On the one hand, human activities contribute greatly to the evolution of oases, such as the expansion of the oasis area (especially the area of artificial oases) [36]; on the other hand, human activities greatly intervene in the stability of oases, for example, overgrazing and over-reclamation make the expansion of cultivated land occur simultaneously with forest and grassland degradation, and this irrational land use, in turn, creates a water resource shortage and a gradual shift from oasisification to desertification [35].

4.2. Study on Spatial-Temporal Evolution of Oasisification

Oasification and desertification are two opposite evolutionary trends in arid and semi-arid regions, and they mutually transform each other under certain conditions, jointly affecting the landscape pattern in arid and semi-arid regions [44]. On the one hand, the change in land-use structure is the external manifestation of the desert–oasis landscape pattern. The evolution of the oasis landscape is mainly focused on the land use changes and

interconversions associated with the oasisification process, with different land use and cover types forming landscape patterns at different spatial and temporal scales [45]. Scholars mainly extracted remote sensing image data on the dynamic evolution of oasisification in the study area, conducted a dynamic analysis of the regional landscape composition, landscape patches, and landscape area changes, determined the spatial and temporal distribution and differential changes of the two landscapes of desert and oasis (natural and artificial oasis) in the region, and determined the scope, degree, and process of oasisification [46,47]. Meanwhile, based on the different land use structures (agricultural land, protective forest belt, and natural vegetation, etc.) playing different functions in the oasis system, the spatial and temporal evolutionary process of oasisification is divided into six categories, natural oasis evolutionary process, engineering protective forest construction process, natural landscape to the farmland transformation process, urbanization process, artificial environment process, and coupled ecosystem process [18]. On the other hand, the change of “water–soil–atmosphere–vegetation” elements is the intrinsic mechanism of the desert–oasis landscape pattern. The changes in the oasis landscape pattern are mainly influenced by the regional hydrological cycle, climate characteristics, soil quality, and biological organisms and have a counter effect on it [48]. The water cycle is the core and premise of the oasis landscape pattern, and its precipitation and evaporation determine the material mechanism of the oasisification process [34]. Soil quality affects the stability of the oasis landscape pattern, and the improvement of soil quality is helpful in preventing the occurrence of environmental problems such as soil salinization [49,50]. Vegetation, as a natural link between soil, atmosphere, and moisture, regulates the climate of arid regions through its cooling and humidifying effects. In summary, these geographic features of water, soil, atmosphere, and vegetation work together in the process of the oasisification landscape evolution [51].

4.3. Study on Ecological-Economic Mutual Feedback Mechanism of Oasisification

The oasisification process is a comprehensive manifestation of atmospheric characteristics, hydrological cycle, soil quality, biological organisms, and their interactions, which determines whether the oasis ecosystem can operate well [17]. Some scholars believe that oasisification provides positive environmental effects in the desertification control, ecological restoration, and land restoration, and that oasisification is conducive to increasing soil productivity, enriching vegetation cover and biodiversity, improving human living space, and enabling benign ecological transformation [52]. However, some scholars believe that oasisification itself may also be an obstacle to the ecological balance in arid and semi-arid areas, a causative and dominant factor of desertification, and that excessive oasisification may lead to inappropriate oasis expansion and reduce the stability of oasis, which is prone to the vicious cycle of “environmental degradation—living poverty—environmental plunder—economic constraints” [37]. When the desert–oasis water ecology is out of balance, it will lead to a series of ecological and environmental problems, such as river drying up, salinization, and vegetation degradation, making the risk of desertification rise and making sustainable socio-economic development unsustainable [53,54]. Other scholars, from a dialectical perspective, suggest that water resources are necessary to ensure the stability of the oasis’s ecological-economic system and that the key to the impact of the rapid development of oases is whether the pursuit of economic benefits by mankind has disrupted the ecological balance between desert and oasis [55]. Appropriate oasisification is conducive to ecological improvement and expansion of human living space, but the low-level disorderly oasis expansion will over-exploit water resources, which leads to ecological problems such as water system changes, shrinking and drying of lakes, the decline of natural and artificial oases, land aridity, desertification, and salinization, as well as socio-economic problems such as the decline in agricultural production and decrease in farmers’ income due to the abandonment of large areas of land [56,57].

4.4. The Oasis Sustainable Development Path in Harmonious Coexistence of Man and Nature

Oases exist and expand due to water, and the scale of an oasis under the rational allocation of water resources is crucial in maintaining the stability of desert–oasis [58]. The carrying capacity of water resources is directly related to the survival of the oasis, and the unreasonable use of water resources will bring inappropriate oasis expansion. When the scale of the oasis exceeds the carrying capacity of water resources, the stability of the oasis is challenged and may be tilted toward desertification [59]. Accordingly, determining the appropriate oasis scale can better control desertification in arid areas, and the oasis scale will eventually reach a dynamic balance with the surrounding desert under the restriction of water resources [60,61]. Therefore, from the perspective of the harmonious development between humans and nature, it is pointed out that the wrong views of “turning sand into the soil”, “turning sand into gold” and “turning desert into good land”, reasonably strengthen the oasisification process in desert areas [62]. Quantifying natural and human factors to determine the appropriate scale of oasisification, and finding the land use structure under the appropriate oasis scale based on the critical threshold of water resources are important paths to the realization of the sustainable development of an oasis [63,64].

4.5. Theory Summary

Based on the above research content and viewpoints of oasisification, and based on the results of the visualization and cognitive analysis of the key literature, the theoretical framework of oasisification research is summarized in Figure 5. The dynamic evolution of oasisification in arid and semi-arid regions is characterized by changes in the spatial and temporal patterns of “desert–oasis” landscapes, resulting from changes in “water–soil–atmosphere–vegetation” elements and land use, where the former is mainly caused by regional ecological and economic influences, and the latter is mainly caused by desert and oasis driving mechanisms. The ideal direction of the oasisification dynamic evolution is to achieve the suitable scale and sustainable development of oases, and the research on the critical threshold of water resources and land use type is carried out around this goal.

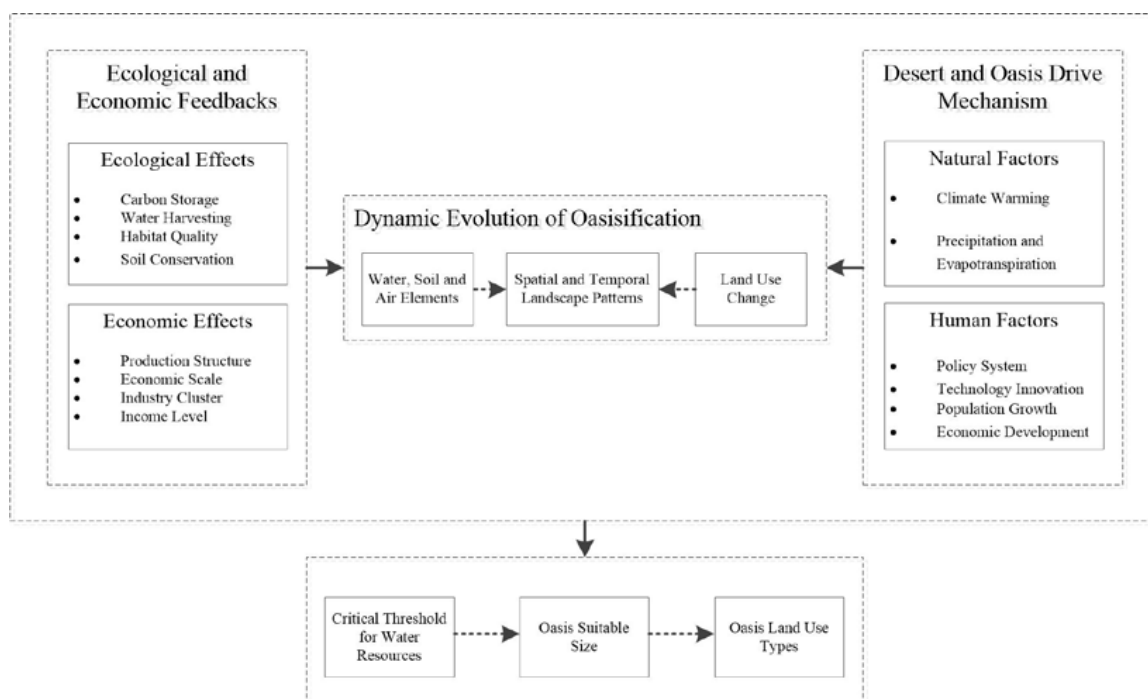


Figure 5. The research framework of the dynamic evolution of oasisification.

5. Discussion

This paper conducts a study based on the literature on oasisification in the CNKI database and the WoS core collection database. From this perspective, the information collected, the analysis taken, the results presented, and the conclusions drawn contribute to the knowledge of oasisification research in arid and semi-arid regions. First, the guiding ideology of this paper is the dialectical philosophical idea of “see the big with the small, see the small with the big”. The overall thesis of this paper is “see the big with the small”, through the “small” keywords in the research literature to present the “big” knowledge system of oasisification research. The analysis of the presented knowledge system of the oasisification research in this paper is mainly “see the small with the big”, through the theoretical framework constructed as “big” to explain each topic and content as “small”. Second, how to maintain the sustainable development of oasisification, not blindly turn the desert into an oasis, and not destroy the organic system of landscape, forest, field, lake, grass, and sand, because each ecological element plays an indispensable role in it, but to conceptually identify and analyze the characteristics and essential reasons for the increase in oasis in reality. Therefore, from the perspective of the scientific development concept, ensuring the stability of the desert–oasis landscape ecosystem is the focus, and desertification control is a long-term task. Under the guidance of a series of ecological management projects, the greening of the country should be determined and measured by water, follow the internal laws of the ecosystem to carry out the construction of forest and grass vegetation and focus on improving the self-healing capacity and stability of the ecosystem, which is the basis for maintaining the stability of the oasis and achieving the sustainable socio-economic development of the oasis, and is an effective way for the oasisification to be managed.

Of course, there are certain limitations in this study. In terms of research data selection, firstly, the Chinese literature was only selected from the CSSCI and CSCD databases, and the English literature was only selected from the WoS core collection database; secondly, only core keywords were included in the setting of search terms. The above two reasons will lead to the omission of some important and academically valuable studies, making the quantitative analysis of this paper inevitably biased, but on the whole, it should not have a major impact on the conclusions and opinions of the literature review. In terms of research case selection, this paper chooses China as a typical case, aiming to explore in depth the research progress of oasisification in arid and semi-arid areas in the Chinese context. However, if only sustainable dryland management in China were studied, the impact of the study and the number of interested readers would be reduced, and the applicability of the study to dryland research elsewhere in the world would also be limited. Therefore, to improve the breadth and depth of research in the field of oasisification, it is our future research direction to study sustainable dryland management from a worldwide perspective by comparing research from China with that from overseas. In the future, the research design including a multi-level, multi-method, and multi-data source (meta-analysis, questionnaire, field experiments, rooting theory, empirical tests, etc.) will be used to study various subdivisional research directions of oasisification for arid and semi-arid regions of the world.

6. Conclusions and Outlook

6.1. Research Conclusions

Based on the research methods of bibliometrics and inductive collation, this paper first combs the current research status of desertification and oasisification in the CNKI database and WoS core collection database. The results show that after a decade of slow intermittent emergence of oasisification research, the number of publications in this field began to increase continuously in 2009. However, compared with desertification research, the research on oasisification is not sufficient, and the understanding of oasisification has not been raised to the same level as desertification. Secondly, the CiteSpace knowledge mapping tool is used to visually analyze 342 and 462 studies on oasisification collected by the CNKI database and

WoS core collection database, respectively. The findings indicate that the research hotspots in this field have experienced four stages of “spatial-temporal evolution, ecological effect, driving mechanism, and sustainable development path”. Additionally, the current research frontiers in desert–oasis ecosystems focus on landscape dynamic evolution, sustainable development, and ecological conservation. Thirdly, this paper reviews the relevant research on oasisification in recent years based on the focus of the research hotspots and goes on to present the main perspectives on oasisification research from four aspects: the driving factors, the landscape form, the eco-economic effects, and the appropriate oasis scale in the evolution of desert–oasis. Finally, based on the results of the above analysis, this paper builds a sustainable research framework of oasisification from the three dimensions of “desert and oasis”, “ecology and economy”, and “man and nature”.

6.2. Research Outlook

Looking back over the past 20 years, research on oasisification has made great progress, and fruitful studies have been conducted on the dynamic evolution of desertification and oasisification, landscape patterns, driving factors, regulatory measures, etc. However, in the long run, there is still much room for development in this field of research, and several of its subfields need more exploration.

6.2.1. Reconstruction of Theoretical Framework of Multidimensional Cyclic Symbiosis System of Oasisification Is Necessary

Compared with desertification research in arid and semi-arid regions, oasisification offers a unique perspective for research, but the theoretical studies on the dynamic evolution of oasisification are few and weak and have not been raised to the proper theoretical level. However, the research on the mechanisms, conditions and laws of oasisification evolution can help to further understand the intrinsic evolutionary laws of arid zone ecological landscape systems and can be a beneficial supplement to the theories related to arid-zone ecosystem balance and oasisology. Therefore, from the perspective of dialectics and system theory, this paper draws on the theory of composite ecosystems to build a multi-dimensional symbiosis of “desert and oasis”, “ecology and economy” and “human and nature”. As shown in Figure 6, it can be used to clarify the energy, material, and information exchange pathways among the systems and units in the cyclic symbiosis system, and to analyze the evolutionary mechanism and comprehensive effects of oasisification. This paper expects researchers to have a new understanding of oasisification from the epistemological level and accelerate the transformation from “oasisification understanding” to “oasisification management”, which not only provides a theoretical reference for the healthy and sustainable development of oases in the process of oasisification but also has great significance for restraining desertification.

6.2.2. Rethinking the Effects of Oasisification in Arid Areas under the Concept of Sustainable Development

The effect of oasisification can be considered from two perspectives: ecological effect and socio-economic effect. Most studies focus on the ecological effect, from the positive ecological effect in the early stage to the negative ecological effect in the recent stage, yet, the comprehensive evaluation of the impact of oasisification from both positive and negative effects is insufficient, and the socioeconomic effect brought by oasisification is not fully considered. The value and significance of the systemic view and sustainable development concept to accurately understand the process and effects of oasisification in arid and semi-arid regions may be greater than any other theories and models. When the process of oasisification in a certain region is examined in a larger spatial and temporal concept, the opinions and judgments obtained may be more scientific and objective. In the future, interdisciplinary research on the evolution mechanism and law of oasisification can be carried out by combining natural disciplines, such as ecology, with humanities disciplines, such as philosophy and economics, and by applying research paradigms and tools of system theory, techno-economics, and ecological economics to systematically and

comprehensively assess the oasisification process under the life community of “desert–oasis” and “human–nature”.

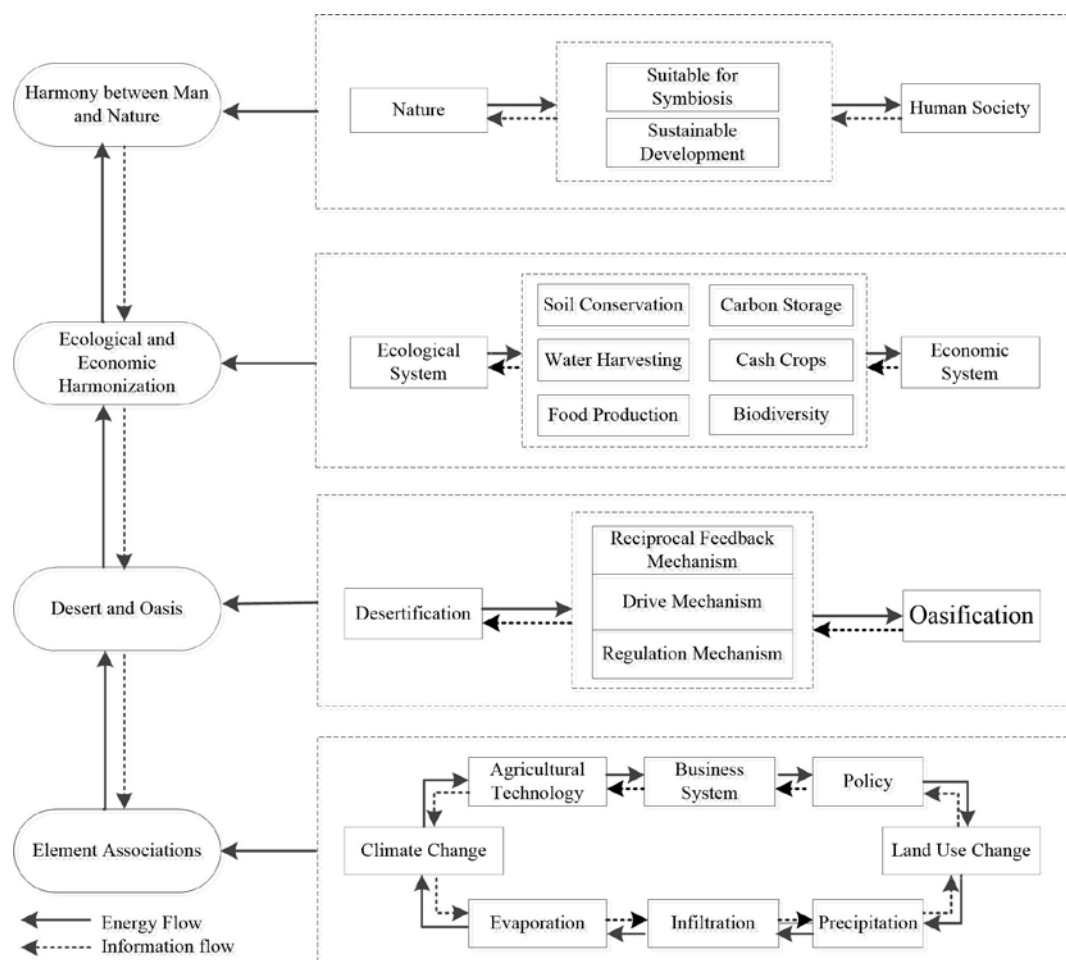


Figure 6. The theoretical framework of multidimensional cyclic symbiosis system of oasisification.

6.2.3. In-Depth Exploration of the Evolution Mechanism under the Optimal Path of Sustainable Development of Oasisification

Most of the studies on the driving factors of desertification and oasisification have remained at the simple classification level of “natural factors” and “human activities”. The impact of climate change and human activities has been agreed upon, but the further subdivision and expression of the key factor of “human activities” is still lacking, which will directly affect the proposal of effective management measures of oasisification. Therefore, in future research, we should dig deeper into the influencing factors behind the driving force of oasisification, break through the interpretation paradigm of “nature, human behavior”, and try to summarize the evolutionary mechanism of the oasisification process from the dimensions of the driving mechanism (climate, soil, water, and technology) and the regulation mechanism (policy and system). This will help to verify the important causal factors influencing the evolution of oasisification, to effectively solve the common ecological and environmental crisis faced by human beings, to provide a reference for decision-making on the commissioning of ecological management projects in arid and semi-arid regions, and to have some practical significance in promoting the revitalization of the villages in oasis areas.

6.2.4. Oasification Management—A Preferred Path for Sustainable Development of Oasification

Although the alternating evolution of desertification and oasification is like two sides of the coin of the ecological evolution in arid and semi-arid regions, desertification management and oasification management are two very different processes. The objectives, subjects, contents, policies, and mechanisms of oasification management need to be further studied. The future oasification management system will not only be satisfied with the critical threshold of water resources to determine the carrying capacity of the oasis but also will be committed to combining the ecological effect analysis with regional economic input–output analysis, deducing the direction and extent of the oasis evolution under different contextual objectives and models, measuring the reasonable development boundary of oasification, and analyzing the balanced layout of oasis ecological and social economic structure. The ultimate goal is to find the appropriate scale and reasonable process to achieve the dual goals of sustainable development of regional oasification and the high-quality socio-economic development of the oasis, and precisely design the optimal path for the sustainable development of the oasis.

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