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Research Progress of Desertification Control in China

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Abstract

Desertification is a change in soil properties, vegetation, or climate that leads to the ongoing loss of ecosystem services essential for sustaining life. Desertification affects large areas of dry land around the world and is a major cause of stress in human societies. Desertification is a serious ecological problem in China. Desertification has seriously affected vegetation growth, food security, and human economy, and has caused certain adverse effects on the natural environment and social environment. Based on the causes of desertification and the present situation of desertification, this paper analyzes various measures to prevent and control desertification and puts forward some useful ideas on desertification in China, which will provide a reference for the research of desertification control in China.

Keywords: Desertification; Causes; Human activities; Desertification control

1. Introduction

Based on the review of desertification literature in China were desertification analyzed. China has a vast territory, and complex terrain, and is located in the eastern part of the Eurasian continent, with a typical monsoon climate. The uneven distribution of water and heat caused by the complexity of terrain and climate causes frequent droughts in China (Yuan et al., 2004). There are many types of climates in China. The climate in the eastern region is characterized by an extensive monsoon climate, characterized by the prevailing continental monsoon in winter, resulting in a cold and dry climate. In summer, the ocean monsoon prevails, and it is hot and humid. The Qinghai-Tibet Plateau has a high altitude, a large area, and a unique alpine climate. The northwest region, because of its inland location, is not affected by the oceanic monsoon force and has an inland arid climate in the westerlies. The arid and semi-arid areas in modern China are mostly distributed in the north latitude of 350, and the annual precipitation is less, which is one of the important reasons for land desertification.

In 1983, the Food and Agriculture Organization of the United Nations (FAO) and the Environment Programme (UNEP) revised the definition of desertification when studying desertification assessment and mapping methods, believing that desertification was the result of climate, soil, economy, society and natural factors, which destroyed the balance among soil, vegetation, atmosphere, and water, resulting in the destruction of production potential, environmental deterioration and the increase of desert landscape (FAO/UNEP, 1984). In 1990, an advisory panel of the United Nations identified desertification and land degradation as the agreed terms (Nash et al., 1999), believing that desertification or land degradation is the land degradation caused by human activities in arid, semi-arid and sub-humid areas affected by thousands of droughts. In 1994, at the negotiating Conference of the United Nations Convention to Combat Desertification, the above definition of desertification was adopted and included in Article 1 (a) of the introduction to Part I of the Convention: “According to academics, desertification is a land degradation phenomenon in arid, semi-arid and sub-humid areas affected by drought due to climate change and human activities.” (The United Nations, 1994). Land desertification refers to land degradation, also known as desertification. In 1997, the first United Nations Conference on desertification put forward the definition of desertification: “Desertification refers to the weakening and

destruction of land biological productivity, and finally, leading to similar desert landscape, it is the process of general deterioration of the ecosystem" (UNCOD, 1997).

Due to the different ideological backgrounds of different scholars, the concept of desertification has accumulated more than 100 definitions (Glantz et al., 1983). In China, Asian and the Pacific coastal region, defined land desertification as: "Land desertification is a process of land resource degradation caused by the interaction between human unreasonable economic activities and fragile ecological environment. This process can trigger a decline in land productivity and eventually lead to desertic-like landscapes on the Earth's surface." In fact, for the definition of land desertification, many domestic and foreign researchers have included the following three points: firstly, the impact of environmental elements refers to desertification occurring in arid, semi-arid, and semi-humid areas and in areas with particularly fragile ecological conditions; secondly, the impact of external factors, especially climate change and human social misconduct; and lastly, the fact of land degradation itself is also a contributing factor (Liu et al., 2000).

Desertification is one of the serious environmental problems (Ma et al., 2005). Currently, desertification has risen from 50000 to 70000 hectares, affecting one-third of the planet and one-fifth of the world population. Desertification is a major ecological problem. At present, more than 100 countries and over 1 billion people around the world are facing desertification risks (Xie et al., 2015; Zhao et al., 2019), which has attracted the attention of the public, the government, and researchers (Zhu et al., 2020; Zhao et al., 2007). From the perspective of areas with extreme drought, African countries have the largest total area, followed by Australia, Russia, the United States, and other countries, and more than 50.0% of the land in Saudi Arabia belongs to extreme arid areas (Zhou et al., 2020).

Currently, 45.6 million square KM of land in more than 100 different countries are vulnerable to desertification, and they are growing by 3.5% a year. About 70 percent of the world's 5.7 billion hectares of arable dry land is degraded and cannot be used for farming, accounting for 30 percent of the total land area. With about 1.4 billion hectares, Asia is the continent most affected by desertification, followed by Africa. Desertification has had a direct impact on more than 250 million people worldwide. Moreover, the threat of desertification affects more than 1.2 billion people. The world economic losses related to desertification have reached $42 billion (including $8 billion in North and South America and $21 billion in Asia) (Zhang et al., 2001).
China is one of the largest desertification countries in the world and one of the most affected regions. As can be seen from Figure 1, the vegetation coverage rate in northwest China is significantly lower than that in the eastern and southern regions. As shown in Table 1, although the area of severe desertification in China is decreasing, the total area of desertification will decrease less. If China's economy and society want to be sustainable, it faces a major threat of desertification. This will affect people's survival and livelihoods, as well as their ability to develop their economy and society in a sustainable manner. The natural environment will inevitably degrade and deteriorate together with human society (Zhang et al., 2001).

Table 1. Dynamic change of desertification

Class	**In 1989, Area / km^2**	**In 2020, Area / km^2**
Heavy desertification	124.03	34.85
Moderate desertification	380.76	228.4
Mild desertification	555.27	576.39
Non-desertification	881.15	1 074.11
Amount to	**1 941.21**	**1 913.85**

However, China has a large desertification and desertification land base. According to the data released by the sixth National Desertification and Desertification Survey, as of 2019, the desertification land area of the country was 257.37×10^4 km^2. The total land area is 250 million square kilometers, accounting for 26.8% of the total land area. The desert area of the country is 168.78×10^4 square kilometers. The total land area is 250 million

square kilometers, accounting for 17.6% of the total Earth's area. The ecological environment of the northern dry and early semi-arid areas is still sensitive and fragile in general (Li et al., 2022; National Forestry and Grassland Administration, 2020).

Over the past 20 years, China's desertification area has increased at a rate of 2,460 square kilometers a year, meaning that China loses a medium-sized county every year. The harm of desertification can be manifested in multiple aspects. On May 5, 1993, a huge sandstorm hit 12 million people in 72 counties and cities in northwest China, killing more than 80 people and destroying nearly 1 billion yuan of assets. In March and April 2000, sandstorms hit half of China more than a dozen times, and in the first few years of the new century, they hit the capital Beijing again. The Yellow and Tarim rivers are in danger of drying up due to the destruction of vegetation in their upstream areas. Similarly, desertification in the upstream region caused a large flow of silt into the Yangtze River, sinking the river, raising the riverbed, and shrinking the lake, leading to major floods and heavy losses in the summer of 1998. The direct economic loss of desertification in China is 54 billion yuan per year, three times the tax revenue of the five western provinces in 1996 (Zhang et al., 2001).

"Partial reversal and overall expansion" are the two main manifestations of land desertification in China. Data show that in the 1950s and 1960s, the area of land desertification increased by 1560 square kilometers year by year, in the 1970s and 1980s to 2100 square kilometers, and in the 1990s, the area of land desertification increased to 2460 km^2 (Dong et al., 1999). According to satellite remote sensing survey technology statistics, 2% of China's grasslands are degraded every year. Inner Mongolia has the largest grassland pasture in China, but in just 30 years, the grassland area of Inner Mongolia has risen from 88×10^6 hm^2 in the 1960s to the current 38.67×10^6 hm^2. The area shrank by 56 percent.

This paper reviews and studies the desertification problem and its control measures in China. Based on an extensive literature review, this paper summarizes the latest progress in desertification research and control in China in recent years. The limitations of previous studies and the needs of future studies are discussed in depth, aiming to provide a useful reference for desertification research in China and other parts of the world. (Liang et al., 2021)

2. Methods

China (73°33′E ~ 135°05′E, 3°51′N ~ 53°33′N) China's vast territory, China's land border as long as 22,800 kilometers, east of the DPRK, north of Mongolia, northeast of Russia, northwest of Kazakhstan, Kyrgyzstan, Tajikistan, It is bordered on the west and southwest by Afghanistan, Pakistan, India, Nepal, Bhutan and other countries, and the south by Myanmar, Laos and Vietnam. To the east and southeast, it borders South Korea, Japan, the Philippines, Brunei, Malaysia, and Indonesia. The total land area is about 9.6 million square kilometers. China's terrain is complex and varied, high in the west and low in the east. The weather in China is complex and variable, subtropical monsoon climate, tropical monsoon climate, tropical rainforest climate, temperate continental climate, and plateau mountain climate, from south to north trans-tropical, subtropical, warm temperate, middle temperate, and cold temperate climate zones. In the eastern monsoon area, there are tropical rain forests, tropical monsoon rain forests, tropical evergreen broad-leaved forests in the middle and South Asia, deciduous evergreen broad-leaved mixed forests in the north subtropical deciduous broad-leaved forest, temperate deciduous broad-leaved forest, cold temperate coniferous forest, and subalpine coniferous forest, temperate forest grassland, and other vegetation types. In the northwest and Qinghai-Tibet Plateau, there are dry steppe, semi-desert steppe shrubs, dry desert steppe shrubs, plateau cold desert, alpine steppe meadow shrubs, and other vegetation types. Precipitation and temperature play an important role in drought change (Li et al., 2021; Li et al., 2022; Tu et al., 2021; Zhu et al., 2021). According to the difference in precipitation, China can be basically divided into arid, semi-arid, sub-humid, and humid regions. Among them, North China and Northwest China are arid and semi-arid regions with small annual precipitation, accompanied by a large range of deserts and grasslands, poor soil water storage capacity, and low soil moisture levels. Northeast China is a humid and subhumid region, but in recent years, the precipitation has continued to decrease, and the temperature continues to rise, so drought mainly occurs in northwest China, North China, and Northeast China. In central, East, and South China, annual precipitation is large, vegetation coverage is high, water retention capacity is

strong, and soil moisture is high, so the above mentioned. The drought degree in the region is light. The Qinghai-Tibet Plateau is dry and rarely rains, and the vegetation cover is mainly alpine scrub. Due to its special altitude and plateau climate, and the spatial distribution pattern of soil moisture and vegetation decreases from east to west, the drought in the western part of the Qinghai-Tibet Plateau is relatively severe Zhu et al., 2021; Li et al., 2012; Yuan et al., 2020; Li et al., 2021).

Based on the review of desertification literature in China and the UK, the spatiotemporal patterns, driving factors, control measures, and research methods of desertification in China were analyzed. The literature search was conducted from January 2000 to October 2023 through CNKI database and Wanfang database, and the keywords were "China" and "desertification" or "land degradation". The first study was published in 1983. Between 1983 and 2000, the number of published papers was less than three per year and began to increase in 2001. Ten papers were published in 2021, indicating that desertification in China has received increasing research attention in recent years.

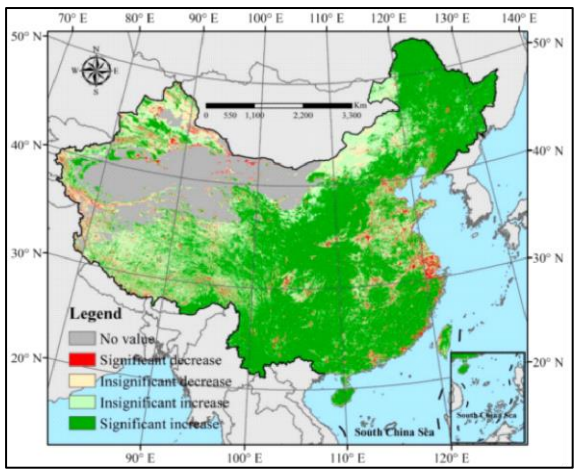

Figure 1. Changes in vegetation cover from 2000 to 2018 based on SPOT (Feng et al., 2021)

3. Results and Discussion

3.1 Types of Land Desertification

By investigating the types, forms, distribution, and activities of desertification, it is helpful to find out the internal and external influencing factors of desertification, further analyze the formation mechanism of deserts, and predict the basis of their spatiotemporal dynamics (Zhang et al., 2018). According to the current research situation at home and abroad, different scholars hold different views on the division of desertification types. For example, the United Nations Environment Programme stated that global desertification will be classified by type of land use (Tomasella et al., 2018). In China, Wang et al. (2003) studied and discussed the desertification in northern China, while Li et al. (1988) initially discussed the desertification types in southern China). They believed that it is practical according to the boundaries of the desertification types because it is easier to determine and conducive to remote sensing assessment. They also divided desertification into steppe desertification, irrigated farmland desertification, and rain-fed farmland desertification. At the same time, they divided the desertification into wind erosion desertification, water erosion desertification, vegetation degradation, and saline (Pickup, 1989) according to the action process. Desertification in Gonghe Basin of Qinghai Province is divided into four categories according to the degree of development, namely potential, developing, strongly developing, and dense desert. These indicators are caused by environmental factors such as wind, vegetation, and soil (Dong et al., 1989). At present, there is no recognized desertification classification system in China. According to the International Convention on Desertification（UNCCD）and relevant

technical regulations for desertification monitoring in China, land desertification is divided into four categories: wind, water, frost, and salt alkali erosion (Li et al., 1988). Each desertification type is classified into four levels: light, medium, heavy, and extremely heavy (Liu et al., 1998). According to the previous research results, combined with the research in recent years, the following land desertification classification system table (Table 2) is proposed.

Table 2. Land desertification classification system (Li et al., 2020)

Type	Sub Classification	Explain
I Role of streaming water	1. The erosion of the barren land	Poor-quality land, met with erosion, such as ravines and collapsed hills
	2. bare rock and soil erosion	Bare bedrock and soil
	3. The accumulation of gravel land	Mudslide flows, landslides, quicksand and other deposits
	4. Soil degradation	Soil impoverishment, coarsening and claying due to soil erosion
II Action of the wind	1. Wind erosion on the barren land	A poor land consisting of wind erosion trenches, grooves and stumps
	2. Half-moving sand dunes blown by the wind	Contains newly activated and formed sand dunes, sand dune chains, sand ridges, etc
	3. Wind-eroded bare land	Bare land and soil
	4. Soil is thickened and diluted	Coarsening and depletion caused by wind erosion
III Chemistry	1. Secondary salinized, acidified, and alkalized land	Secondary salinization, acidification, and alkalization of the soil
	2. Three waste pollution	Land desertification, mainly caused by water pollution
	3. Pesticide and chemical fertilizer pollution	Overuse of pesticides and chemical fertilizers
The human role of oneself	1. Storage of waste soil, waste rock and waste residue	Accumulation of waste soil, waste rock and waste residue produced by industrial and mining development
	2. Artificial excavation of barren land	Poor-quality land formed by artificial mining and activities

3.2 The Causes of Land Desertification

Human activities are closely linked to the formation of desertification. In China, the proportion of population density has already exceeded 2 people/hm^2, even reaching 10 people/hm^2. This figure already greatly exceeds the internationally accepted figure of about 1 person/hm^2 (Dong et al., 1999). Land desertification is caused by the joint destruction of natural factors and human activities. Slow and long-term desertification is generally caused by natural reasons, and the main cause of desertification is attributed to unreasonable human activities (Dong et al., 1989). The increase in population has increased the need for water resources, while the difficulty and cost of combating desertification are also rising.

3.2.1 Natural Factors

Climate change caused by climate change (especially continuous, severe drought, etc.) intensifies plant and soil erosion in the process of desertification and then causes desertification. In China, most of the arid, semi-arid, and sub-arid regions are located in inland, with the least precipitation, the largest evaporation, and the heaviest drought degree, and are also the most easily affected by drought region (CCICCD., 1996). Under dry conditions, land desertification increases, and under wet conditions, land desertification reverses. In recent years, a number of sand and dust storms have occurred consecutively in northern China, with desertified areas (about 2.5 million hectares) focusing on the west-central part of the Inner Mongolia Autonomous Region and the northwestern part of Hebei Province (north-west of Beijing) as the priority regions (General Forestry Bureau of China, 1996). The frequent sandstorm weather in northwest and northern China has further aggravated the desertification process in this region.

3.2.2 Human factors

China has had an increasing population since ancient times. In arid areas, the cultivation mode of "extensive planting and thin harvest" has been formed due to the lack of water resources and nutrients, the annual precipitation fluctuates greatly, and the crops are unevenly harvested, so the original large-scale forest land and grassland have become farmland in the middle and lower reaches; Due to the drought and strong winds, farmland gradually turned into desert. It is difficult to meet the rapid development of food demand because of the harsh conditions in desert areas. The grim facts have prompted the local people to strive to improve their land area and increase their grain reserves. Conversely, the development of sandy land will cause serious damage to forests and grasslands, thus causing a vicious circle of cultivated development, land development, land utilization, land desertification, and redevelopment. According to historical records, during the Qin and Han Dynasties, Maoshan was once a territory suitable for the development of agriculture and animal husbandry, which was “fertile land with rich warehouses and households” and “lush grass and sheep blocking the road”. Coupled with the invasion of foreign forces at that time, the pasture was seriously damaged, thus accelerated the desertification.

Long-term disorderly farming extensive farming and animal husbandry violate the natural laws of nature and destroy the local ecological balance. The damaged environment has not been restored and protected in time and effectively, and land desertification is inevitable. Among the factors causing the continuous expansion of desertified soil in China, overgrazing is the main cause of desertification (CCICCD., 1996). According to the report (General Forestry Bureau of China., 1996), grassland degradation in China is increasing at a rate of 2.6% per year, and the degraded grassland in the country has increased from 86.67 million hm^2 to 130 million hm^2 in 10 years, with an increase of 4.333 million hm^2 per year. The typical area is the Hunsendak Sandy land in central Inner Mongolia. Some scholars have analyzed the ecological environment of Inner Mongolia since 1999 by using the vegetation precipitation utilization index and found that the overall pattern improved, but the precipitation in this region changed greatly, and the boundary between drought and extreme drought changed abnormally (Jiang et al., 2005). The main reason for the emergence of deserts in this region is overgrazing by local residents, resulting in a decline in sustainable grassland change in Inner Mongolia. The sustainable development of Inner Mongolia grassland has gradually declined, and the critical value has begun to approach unsustainable. In recent years, most pastoral areas blindly pursue the number of herds, while ignoring the improvement of herd quality. Overgrazing results in increased areas of grassland, vegetation reduction, thinning, and bare land. However, the unreasonable development, utilization, and management of water have been leading to a lot of waste and the death of local plants. Atmospheric groundwater resources are the main sources of water resources in arid and semi-arid areas. As a result, the soil surface is gradually desertified by more than 80%. In the Iginhoro flag region, the water level is still 30m lower than the water level in the 1950’s.

Environmental degradation and development are inseparable and interdependent, and long-term environmental degradation will have a certain negative impact on the development of the local economy. Forced by livelihood and lack of awareness of environmental protection have led to the destruction of forests and grasslands, and the gradual reduction and degradation of good forests and grasslands. According to the survey (Cui et al., 2004) in

Erdos City, at least 15 million kg of licorice and 1 million kg of Ephedra are collected annually. According to calculated statistics (CCICCD., 1996), for every 1 kg of licorice collected at least 267-333,000 hm^2 of grassland was destroyed, and the area of grassland destroyed in the city amounted to 267-333,000 hm^2; in the mid-1980s, digging for medicinal herbs and woodcutting had already destroyed more than one-third of the vegetative cover.We often overestimate human society, thus violating the laws of nature. During the process of prevention and control, they blindly followed, without combining with the local actual situation, and turned the originally stable wilderness area into a desertification area. With the increasing demand for life, the demand for wild animals is also increasing, resulting in the lack of a link in the food chain in the biosphere. In addition, China's legal system for combating desertification is not perfect, and there is no law to fully protect ecology, natural resources, and environmental protection. The lack of these aspects, to a certain extent, limits the effective implementation of the responsibility and rights of desertification control and even leads to the ideological problems that some people "have nothing to do with me, and it doesn't matter whether it is cured or not".

3.3 Measures to Control Land Desertification

To sum up, desertification is land degradation caused by human activities acting on the fragile ecological environment. Therefore, the study of desertification should mainly focus on the relationship between man and land and their interaction (Yin et al., 2016; Zhang et al., 2020; Qiu et al., 2003; Wang, 2000a).
Land desertification is mainly caused by human activities. The natural factors to improve the effect of desertification can be said to be minimal, and legislation should be strengthened from the perspective of human nature. Combating desertification according to law, the state and governments at all levels use laws to regulate people's production, life and activities, so that people dare not touch the legal bottom line of desertification. In addition, strengthens the propaganda of desertification control, makes people form a good environmental awareness, and promotes the prevention and control of "desertification" from both legal and social aspects.

3.3.1 Control the Increase in Population and Improve People's Thinking About Desertification Control

China has one of the fastest-growing populations in the world. Taking the data from the fifth to the seventh national population censuses as an example, the population size of 35 big cities in China was 146.66 million at the end of 2000 and 30.88 million at the end of 2020, with a population growth rate of 10.15% in the past 20 years, and the average population size of each city increased by 4.41 million net, and the city size expanded rapidly (Wang, 2000b). As a result of scientific and technological progress and social development, the main limiting factor for economic and social development has become population growth. From 2000 to 2017, China contributed 25% of the global "green increase" with 6.6% of the global vegetation area, of which ecological projects led by the forest and grass industry contributed 42% (Wang, 2001). Vegetation coverage in northern China increased significantly in the 33 years from 1981 to 2013, and the increase was most significant in the Loess Plateau, Northeast China, and central Xinjiang. This study analyzed that the "greening" of ecological engineering in northern China was the main force (Wang & Zhu, 2001). From 2000 to 2010, China contributed half of the carbon sequestration in the project area through national major ecological projects (Wei, 2022). Since 2000, China's net restored land area has ranked first in the world, contributing nearly one-fifth of the world's net restored land area (Chen, 2019). It shows that the population education in China in recent years has had some effect. However, the agricultural and pastoral areas in the north of China are not optimistic either. Its desertification area accounts for 63.80% of the national desertification area, and the annual growth rate of sandy pasture is 1.39%, up to 4.66% (Wang et al, 2020). By analyzing the causes of desertification, we can know that if human society does not pay attention to this environmental problem and take corresponding measures to save it, desertification in China will become more and more serious in the future. Human beings and the environment are integrated, and the destruction of the environment will also affect the survival and development of human society. Therefore, the control of land desertification must adhere to the people-oriented, implement measures, and pay attention to sustainable development, rather than empty talk. Controlling population growth can slow down land desertification to some extent. But what is more critical than controlling the quantity should be population education. Desertification control is a social problem, which is closely related to everyone in society. It is of great significance for people to protect the environment and prevent desertification to educate and supervise the public through the media, improve their quality, and promote the harmonious development

between man and nature, thus enhancing their understanding of these issues.

3.3.2 Optimize the Livestock Structure, Using Artificial Or Semi-Artificial Grass

At present, in areas with relatively fragile ecological environments in China, relevant measures have been taken to change farmland into forests and grassland, close mountains, and ban grazing. Firstly, measures such as planting grass, reseeding, and water-saving irrigation are taken to increase feed supply from the root and ensure the food source of livestock; second, to optimize the livestock structure; third, to implement zoning and rotation grazing to give pasture certain rest time so that the pasture can adjust and restore; fourth, to actively develop agriculture and support livestock raising. In addition, in northern China, due to the cold climate, it is difficult for livestock to survive the winter if feed is scarce. Therefore, we can plant artificial grass or semi-artificial grass to reduce the impact of natural factors on feed supply, to replenish the soil, which is an important measure to solve the problem of winter and spring cattle overwintering. The experiment shows that the effect of (Li et al., 2021) in desert grassland is very significant. In terms of the results, this method is feasible. Not only can it repair the environment, but it can also give the environment time to breathe and rest and strengthen the sustainable development of the environment.

3.3.3 Strengthen the Awareness of Water Saving and Take Measures to Control Sand According to Local conditions

According to the study, the yield of sandy corn soil can reach up to 9,000 kg / hm^2, but it requires eight times of irrigation, requiring 40 tons of water each time. Moreover, most of this water has evaporated, so we should try to minimize the area of sand used for agricultural cultivation. Research shows that the degree of desertification in an area is positively correlated with the awareness of water resources and local population. If the local population has a good awareness of water saving, then the local water waste will be reduced. At the same time, we should also consider the relationship between forest and grass, and plant trees and grass according to local conditions, rather than “blindly cutting grass”. In view of reserve ecological land, land management and restoration should be strengthened, both “governance” and “use” should be taken into account, and land “increment” should be reserved for future development (Liu, et al., 1994; Wu et al., 2020). In addition, in the process of afforestation, natural plant varieties should be selected as far as possible to promote ecological restoration and slow down soil erosion. Building water conservancies and ensuring the rational development and utilization of water resources are also effective measures to alleviate land desertification. Some countries with serious desertification, such as Israel, have adopted advanced drip irrigation and sprinkler irrigation technologies to alleviate desertification and improve the effective use of water resources. In addition, controlling grassland logging and using desert light and heat resources as civil fuel are also important methods to control desertification.

3.3.4 Develop the “Ecological Chain” and Extend the Industrial Chain

Developing the "ecological chain" and extending the industrial chain is a comprehensive approach aimed at promoting sustainable development and economic growth while preserving the natural environment. This strategy involves creating a harmonious interplay between various ecological components and industries, fostering a symbiotic relationship that benefits both nature and society. Protect the species in the ecological chain and avoid the partial absence of the ecological chain. At the same time, we can extend the industrial chain to achieve the coexistence of resource benefits and economic benefits. For example, in Israel, by combining the food, melon, and flower industry chains, both environmental and economic benefits are realized (Zhang et al., 2001).

3.3.5 Taking Comprehensive Consideration, Give Full Play to the Predictive Role of High Technology

The characteristics of desertification in China are more complex causes, high incidence rate, great harm, more types, and rapid development (Li et al., 2004). Despite long-term national efforts and research, China's land desertification has achieved a certain degree of effect, but the situation is still not too optimistic. The following

situations often occur in the process of desertification: fewer quantitative studies, more qualitative and semi-quantitative studies; many studies only focus on theory, poor practical ability, ignoring the combination of theory and practice; research fields are very narrow; research more traditional methods, rather than cutting-edge high-tech environment simulation technology. Despite the catastrophic sandstorms and heavy losses, the government implemented timely and effective prevention and control efforts in the 1930s. According to the report, the United States sprinkles water to the soil 48 hours early before the wind comes, making it tight, thus reducing the phenomenon of sand moving in the wind and effectively curbing sandstorms. The US measures inspire us to some extent, but in China's arid, semi-arid, and sub-humid areas, the combination of desertification control and the effective development and utilization of desertification land is another key requirement. Therefore, it is necessary to introduce new theories, new technologies, and new methods to combat desertification in China, so as to realize comprehensive thinking, comprehensive planning, early warning, and prevention in the bud.

4. Conclusion

This article systematically examines the latest progress in the spatiotemporal distribution, driving factors, governance measures, and research methods of desertification prevention and control in China. It summarizes the current research progress and future development directions (Liang et al., 2012).

i. China's desertification control has progressed significantly over 60 years, with models accumulating and ecological improvements. Desertified land has shifted from annual expansion to reduction. Remote sensing aids monitoring but faces limitations in resolution and timeliness, hindering accuracy (Gong et al., 1969). Future monitoring necessitates high-resolution, timely data for enhanced understanding.

ii. The desertification of land in China is the result of the joint action of natural and human factors, and we should pay attention to various mechanisms and factors to control desertification.

iii. China has established desertification control systems tailored to regional characteristics (Lin et al., 2003; Lu et al., 2021), such as the "solid base and resistance" model for Baoland Railway's Shapotou section, Kubuqi's eco-wealth creation model leveraging gov't (State Forestry Administration of the People's Republic of China., 2015), enterprises, & masses, water-based "low coverage" model in arid/semi-arid regions (Lu et al., 2000), and Hotan models suited to extreme arid areas. This forms a Chinese model of desertification control.

iv. Contemporary research mainly adopts field investigation, experiment, remote sensing, and modeling methods to study desertification in China.

Desertification is a global challenge requiring recognition of its long-term, complex, and difficult nature. The fight against desertification continues, necessitating increased scientific and technological efforts to innovate solutions. Enhancing public awareness of sand control and environmental protection (Guo et al., 2017), and fostering cooperation between science, technology, and humanity, are crucial to tackling environmental challenges together.

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Declaration of Conflicting Interests

All authors declare that they have no conflicts of interest.

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