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Research on Ecological Restoration Technology in Arid or Semi-arid Areas from the Perspective of the Belt and Road Initiative

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Abstract: In the new era of the rapid development of economic globalization and the community of human destiny, the implementation of the “One Belt and One Road” (OBOR) construction model is designed to coordinate environmental protection and economic development. Most of the countries along the Silk Road in the 21st century are developing countries, and the majority of them are facing the same ecological and developmental difficulties as China. In this paper, under the background of the “OBOR” strategy and on the basis of the distribution of global climate types, we selected Central Asia and Northwest China, which have temperate continental climates, as the research objects. We sorted out and summarized the main ecological problems faced by Western China and Central Asia during the development of the “Belt and Road” initiative. At the same time, in combination with the major ecological governance projects implemented in recent years, we proposed key ecological governance technologies that have a certain degree of scalability, such as key technologies for water resource utilization and protection, sand prevention and control, and saline-alkali land governance. The aim was to offer the experiences and a reference for providing technological models for the “one belt along the road” region and the country to build an effective ecological governance system. Two suggestions are then proposed for improving the feasibility and rationality of ecological governance technology in the construction of the “One Belt, One Road”. 1) With the implementation of the strategy of “OBOR” construction, the ecological threats the OBOR countries are facing cannot be ignored. Every country needs to jointly act to build an “OBOR” ecological civilization. 2) The participants must pay attention to the spatial heterogeneity and temporal dynamics of ecological carrying capacity, and provide data reference and support for the reasonable allocation of ecological governance technology.

Key words: the “Belt and Road” initiative; ecological civilization; ecological governance; ecological restoration technology

1 Introduction

More than two millennia ago, the diligent and courageous people of Eurasia explored and opened up several routes for trade and cultural exchanges that linked the major civilizations of Asia, Europe, and Africa. These routes have been collectively called the Silk Road (SR) by later generations.

The ancient SR is a road for communication between China and foreign countries and for the mutual exchange of commodities (Fig. 1). The SR originated in China. It passes through Central Asia, South Asia, West Asia, Europe, and North Africa, covering nearly 30 countries, with a total length of nearly 8000 km (Qi et al., 2019; Sun et al., 2019;

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Yu et al., 2020). Over the past hundred years, the spirit of the SR has been passed down from generation to generation, promoting the progress of human civilization and becoming an important link for the prosperity and development of the many countries it passes through. It is a symbol of exchange and cooperation between the east and west, and is also the world's historical and cultural heritage (Li et al., 2014; Chen et al., 2017; Zhu et al., 2019).

In the 21st century, as a new era with the themes of peace, development, cooperation, and win-win, inheriting and continuing the spirit of the SR is important given the weak global economic situation and complex international and regional relationships. In September and October 2013, during a visit to Central and Southeast Asian countries, Chinese President Xi Jinping put forward a proposal for cooperation in building the "SR Economic Belt" and a "21st Century Maritime SR," referred to as "the Maritime" (Fig. 2), which has been receiving increasing attention from the international community (Cai et al., 2018; Duan et al., 2018).

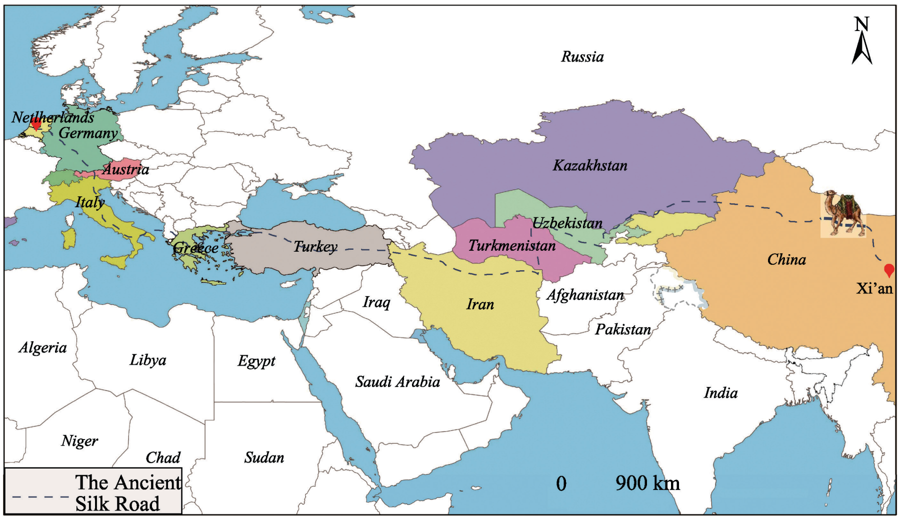

Fig. 1 The route map of the ancient SR

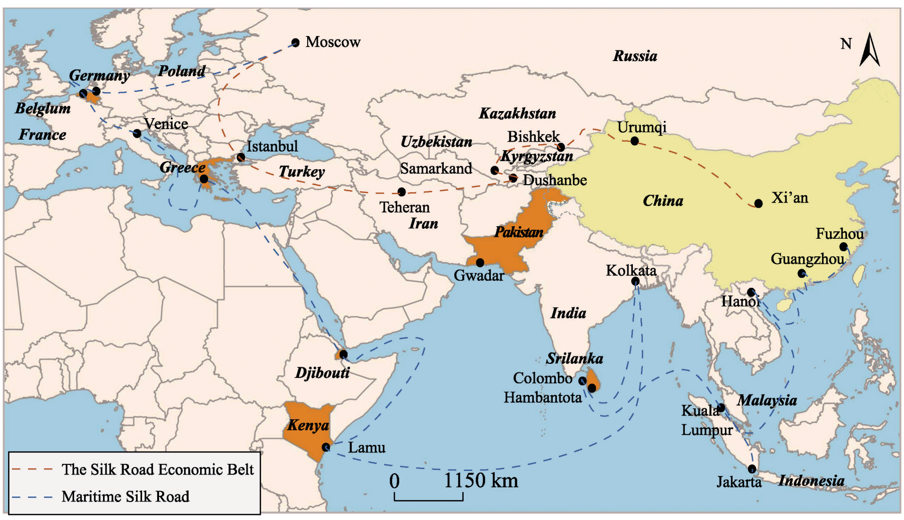

Fig. 2 The road map of the modern "OBOR"

The ancient SR was once a road to prosperity for civilizations. However, as time progressed, the deterioration of the ecological environment led to the severance of the "Mesopotamian civilization" (Mesopotamian and Kroraina civilization). More than 2000 years of significant change has altered the planet we live on. Economic globalization, social information, and even the data revolution have ushered us into a new era of a shared future for mankind. In June 2016, President Xi Jinping delivered a speech at the Supreme Court of Uzbekistan legislature emphasizing that "ecological prosperity is civilized and prosperous, and ecological decline is a decline of civilization." The implementation of the "OBOR" construction model is designed to coordinate environmental protection and economic development, increase the protection of the ecological environment, and facilitate working together to create a "Green SR" for promoting the development of a green economy. The ecological environment of many countries and regions is inherently fragile. With the increase in cooperation among various industries, such as energy, the "one belt and one way" ecological environment will not be achieved if the proper level of importance is not afforded to environmental protection. The negative externalities caused by environmental pollution will hinder further cooperation among the countries and regions in the future.

Most of the countries along the SR in the 21st century are developing countries, and the majority of them are facing the same ecological and developmental difficulties as China. In terms of natural conditions, the Middle Eastern and Central Asian areas along the belt and road are facing major threats, such as shortages of water resources, land desertification, and rising sea levels. In Kazakhstan, for example, approximately 66% of the land has become gradually degraded, and nearly 180 million hectares is desertified (Zhao et al., 2002; Kuang et al., 2014). Several of China's regions along the route are not in good condition. For instance, land desertification in the middle and western regions of Xinjiang and Ningxia is severe, and the soil erosion rate in several areas has reached 64.34% (Yuan et al., 2003). The Chinese Academy of Sciences also indicated that global warming will accelerate the melting of glaciers by around 2045, and Xinjiang, Central Asia, and other places in China may experience a notable reduction in river runoff (Wang et al., 2016). Difficulties in development and construction along the "one belt along the way" and the fragility of the ecological environment can be very closely linked. The fragility of the ecological environment restricts the economic and social construction in the countries and regions along the "OBOR". Nevertheless, most scholars have focused on the economic development, political diplomacy, and cultural exchange of the "one belt and one road," while minimal attention has been paid to the strategic orientation and function of the environment and ecology (Du et al., 2017; Yu et al., 2017). In fact, the construction of "OBOR" is not only an opportunity for economic, diplomatic, and cultural cooperation but also for cooperation in environmental protection and ecological governance. Therefore, ensuring the sustainability of resources and the environment is a major challenge for the implementation of the "SR Economic Belt," and environmental protection has become a fundamental guarantee for the steady development of the "OBOR". Numerous national ecological projects have been launched during the implementation of the major strategy of "OBOR" construction in recent years (Xu et al., 2018; Zhu et al., 2019). Their key technologies have provided scientific support for the comprehensive management of the ecological environment, with successful outcomes. China has the experience, ability, and responsibility to provide enhanced technology for other less developed countries and regions in the "OBOR" model. However, the technology, mode, and experience of ecological management proposed in the "OBOR" model in response to regional ecological problems have not been addressed in the relevant research. This shortcoming is not likely to result in a green "OBOR" of high quality. Thus, a comparative analysis method was used herein to analyse the main ecological problems faced by China's "OBOR" development process and the limitations of ecological restoration from the perspective of space. For the first time, the key technology of major ecological projects under the background of "OBOR" is introduced. This study aims to

Table 1 Countries along the belt and road

Asia					Central Eastern Europe	CIS	Africa	West Europe
West Asia	South Asia	Central Asia	East Asia	ASEAN				
Iran	India	Kazakhstan	Mongolia	Singapore	Lithuania	Russia	Egypt	Greece
Iraq	Pakistan	Uzbekistan		Malaysia	Estonia	Ukraine		
Turkey	Bengal	Turkmenistan		Indonesia	Latvia	Belarus		
Syria	Sri Lanka	Tajikistan		Myanmar	Czech Republic	Georgia		
Jordan	Maldives	Kyrgyzstan		Thailand	Slovakia	Azerbaijan		
Lebanon	Nepal			Laos	Hungary	Armenia		
Israel	Bhutan			Vietnam	Slovenia	Moldova		
Palestine				Cambodia	Croatia			
Saudi Arabia				Brunei	Bosnia and Herzegovina			
Yemen				The Philippines	Montenegro			
Oman					Serbia			
The United Arab Emirates					Albania			
Qatar					Romania			
Kuwait					Bulgaria			
Bahrain					Macedonia			
Cyprus					Poland			
Afghanistan								

Note: ASEAN is the Association of Southeast Asian Nations; CIS is the Commonwealth of the Independent States.

provide a reference for building a "one belt and one way" ecological management system and is of great significance for improving the global development mode and promoting global ecological governance.

2 Countries and climate types along the "OBOR"

The "SR Economic Belt" and "Maritime SR Economic Belt" involve 64 countries and regions (Table 1), including Mongolia in East Asia, 10 countries in the Association of Southeast Asian Nations (ASEAN), 17 countries in West Asia, seven countries in South Asia, five countries in Central Asia, seven countries in the Commonwealth of the Independent States (CIS), and 16 countries in Central and Eastern Europe, there is a country in northeast Africa and a country in West Europe. In accordance with the division of global climate types (Ci et al., 2002), the main climate types include the monsoon climate of medium latitudes, tropical monsoon climate, temperate continental climate, Mediterranean climate, and tropical desertification climate.

3 The ecological dilemma of countries and regions along the belt and road

3.1 Ecological problems in Central Asia

Central Asia is at the core of the SR Economic Belt. If the unique natural resources are effectively developed, they can provide strong material support for the construction of the SR Economic Belt. However, the exploitation of these resources has long been seriously restricted by the increasingly fragile ecological environment in Central Asia. This vulnerable ecological environment is mainly manifested by water over-exploitation, the drying of the Aral Sea and desertification. 1) The climate is dry, and the water resources have been overexploited. Central Asia is located in the north temperate zone, and more than 80% of the land is covered by deserts, especially Turkmenistan, with a high temperature in summer. The annual precipitation in these areas is less than 100 mm, but the evaporation is more than 2000 mm (Huang et al., 2013). 2) The drying of the Aral Sea has become a serious ecological disaster. The water surface of the Aral Sea is shrinking, the groundwater level is falling, the salt and alkali at the lake bottom are exposed, and "white storms" (salty storms) occur in rapid succession. These phenomena have immeasurable and considerable impacts on the surrounding farmlands, grasslands, and residents. Nearly 2 million hectares of arable land and approximately 15% of the pastures have been swallowed up by the Aral Sea desert. The economic loss of the entire Aral Sea basin area has been more than 30×10^9 USD, and it will have an impact on the future climate (Hu, 2009; Wu et al., 2009). 3) Large-area reclamation has led to vegetation destruction and serious desertification. From 1954 to 1979, the Soviet reclamation movement rapidly expanded the cultivated land area, which increased the grain production greatly but it also destroyed a large area of natural vegetation, and caused land desertification, soil wind erosion, and black storms from time to time. Different degrees of desertification and grassland degradation have also occurred due to the large-area reclamation and endless misuse of natural pastures and grasslands. For example, there is severe secondary salinization of the soil in several areas in Kyrgyzstan due to overgrazing and the long-term use of traditional irrigation methods. The overuse of river water has also sharply reduced the lake area, resulting in a decrease in the ability of the lake to regulate the climate, and over-reclamation has led to the intensification of land desertification.

In general, with increasing population pressure, the impacts of global climate change, the falling water level of the Aral Sea in Central Asia, and the trends in land salinization, impoverishment, extreme drought, and surface vegetation degradation have all become increasingly serious.

3.2 Ecological problems in Northwest China

Based on the division of global climate types, most of Northwest China and Central Asia have a temperate continental climate. As an important area of the "OBOR", North China is not well endowed with ecological resources. It is also one of the areas experiencing the most prominent ecological problems, which are mainly reflected in the three aspects of water shortage, land desertification and land salinization.

(1) Water shortage

Water resources are the key constraint factor for social and economic development and ecological environment protection in arid and semiarid areas. Northwest China accounts for 35.9% of the total land area of China, has a typical continental arid and semiarid climate area, and is situated far inland. The rainfall in most areas is less than 400 mm, the evaporation capacity exceeds 1000 mm, and the water resources are only 73600 m^3 km^{-2}, which is equivalent to one-fifth of the national average level (Deng, 2018) (Table 2). From the perspective of basin ecosystem health and safety, the utilization of water resources in Northwest China is unreasonable. Northwest China has a vast area with few people, and its economic development is relatively outdated. The cultivated land area accounts for 14% of the country, but the grain output only accounts for 8%. The GDP and industrial output value only account for 5.6% and 3.1% of the national totals, respectively (Min et al., 2003). For the One belt, one road, statistics include the water supply quantity (surface water, groundwater, and per capita water resources) and water consumption (agriculture, industry, life, and ecology) of several provinces and autonomous regions in China. From the perspective of water consumption, the highest annual average water consumption in 2014–2018 was recorded in Xinjiang, reaching 56.512×10^9 m^3; the lowest was in Qinghai, which was only 2.631×10^9 m^3. The shortage of water resources is the most important factor in the deterioration of the ecological environment. In the northwestern region, the phenomenon of economic water occupying agricultural water and ecological water is widespread and has seriously affected the regional ecological environment security. The eco-environmental problems caused by the unsustainable use of water resources are mainly manifested in four aspects. First, the excessive development of water resources causes the deterioration of the ecological environment. The connections between tributaries and the main stream in the basin are obviously weakened, whereas the connections among the upper, middle, and lower reaches of the main stream are evidently strengthened. Water resource consumption is concentrated in the middle reaches of the main stream, which causes the natural oases in the lower reaches to shrink and land desertification to accelerate. Second, the improper utilization of water resources and excessive irrigation quotas have led to secondary salinization of the soil. Third, water pollution results in the deterioration of surface water and groundwater quality, such as in the middle section of the northern slope of Tianshan Mountain and the eastern Xinjiang area, the Shiyang River, and the Yellow River Basin in Hexi Corridor in Gansu Province. Most of the surface water and groundwater in these areas has been transformed and utilized three times. The downstream water quality has seriously declined, and the ecological environment has rapidly deteriorated. Fourth, severe soil erosion and degradation of the ecological environment quality are apparent. In several areas, the shortage of water resources has affected peoples' lives and has even directly threatened human survival. Since the 1970s, the drought trend in Northwest China has become increasingly serious, which has severely restricted and hindered industrial and agricultural production and regional sustainable development. The most restrictive factors for the realization of sustainable development in the 21st century in Northwest China are water resource shortages and the resulting ecological environment problems (Zhou et al., 2001).

Table 2 Statistics of water resource utilization in Northwest China in 2015

Region	Water supply ($\times10^9$ m^3)				Water consumption ($\times10^9$ m^3)				
	Surface water	Groundwater	Recycled water	Subtotal	Agriculture	Industry	Life	Ecology	Subtotal
Xinjiang	456.9	119.4	0.9	577.2	546.4	15.0	10.0	5.8	577.2
Ningxia	59.4	5.3	0.2	64.9	57.7	4.4	2.1	0.7	64.9
Northern Shaanxi	32.8	30.0	1.7	64.5	37.3	11.8	12.7	2.6	64.4
Northern Gansu	88.7	26.5	1.6	116.8	94.8	11.3	7.5	3.1	116.7
Northern Qinghai	13.8	2.8	0.0	16.6	12.1	1.6	2.2	0.3	16.2
Western Inner Mongolia	71.1	38.9	2.5	112.5	82.3	10.1	5.7	14.4	112.5
Total	722.7	222.9	7.0	952.6	830.6	54.2	40.2	26.9	951.9

Note: Data source: http://www.stats.gov.cn/.

(2) Strengthened land desertification

Within the SR Economic Belt, Gansu, Xinjiang, Inner Mongolia, and Shaanxi are the main provinces (regions) experiencing desertification in China. Most of their areas are occupied by mountainous plateau landforms. They are not only the river sources of China but also the sources of sandstorms. Given the distance from the sea, the climate is dry, the surface vegetation coverage is low, and the ecological environment is fragile. In accordance with the indicators stipulated in the United Nations Convention to Combat Desertification, China has about 2.61×10^6 km^2 of desertified land, accounting for 27.20% of China's land area, and the population affected by desertification is about 400 million people. The speed of the expansion of the desertification area and its intensity are further increasing, which leads to the degradation of cultivated land to different degrees and continues to encroach on the oases on which people depend. With the expansion of desertification, vegetation degradation, and man-made destruction, the number of sandstorms in this area has increased dramatically, which has seriously harmed the social and economic development of this area and its surrounding areas (Schlesinger et al., 1990; Hardenberg et al., 2001; Karamesouti et al., 2018).

(3) Land salinization

Six provinces in Northwest China (Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, and Inner Mongolia) have more than 30 million mu of salinized soil, accounting for 69.03% of the total area of saline soil in China (Gou et al., 2011). This is the result of the high soil salt content and improper irrigation methods. In several areas, the exploitation of groundwater has led to a decrease in the groundwater level, a decrease in the phreatic water evaporation supply for surface vegetation, a decrease in biomass, serious desertification of the soil, the strengthening of wind and water erosion, and secondary salinization of the soil, all of which seriously affect crop yields, decrease the soil quality, and increase the abandonment of land. For example, in the Shiyang River Basin in the east of Hexi Corridor in Gansu Province, the groundwater level has dropped by 2–17 m in the last 20 years, forming three groundwater funnel areas of 986 km^2 in the oasis (Li et al., 2012). The mineralization degree of groundwater in Minqin region, which is located in the lower reaches of the basin, has increased by 1–7 g L^{-1}. Consequently, 76000 people and 124000 livestock have restricted access to drinking water, and 24667 ha of good farmland has been abandoned. This phenomenon has forced the population to move out gradually, so this area has become a typical example of regional ecological environmental deterioration. The salinization and secondary salinization of the soil caused by irrigation are the main obstacles to agricultural development and are important factors contributing to the instability of the ecological environment in arid Northwest China (Li, et al., 2012).

4 Promoting key technologies for ecological governance to boost the construction of the ecological environment

The Central Asian region crossed by the SR Economic Belt and the northwestern region of China are consistent in their climate type. They experience very similar ecological problems and are typical ecologically fragile regions. Therefore, numerous successful control technological models and countermeasures have been developed for the comprehensive control of the ecological environment in Northwest China in recent years, such as the "Three North" Shelterbelt System Construction Project, the national desertification control project, and the Beijing-Tianjin-Hebei sandstorm source control project (phases I and II). These efforts offer an approach for the protection and management of the ecological environment in Central Asia and have achieved a high degree of popularization.

5 Key technologies for water resource utilization and protection

Most areas in Central Asia rely on water diversion irrigation. The agricultural areas that use irrigation are mainly distributed in Kyrgyzstan and Tajikistan. Broad irrigation is still the main irrigation method. Water shortages have posed certain constraints to the planting industry in Central Asia. Similar problems also exist in Northwest China. In accordance with the analysis of the development and utilization degree of water resources (on the basis of the water supply in 2015) (Table 3), the development and utilization rate of water resources in the entire country is 22.6%, while that in the northwest is 59.8%, which is remarkably higher than the national average level, especially in the Shiyang River Basin, Heihe River Basin, Tarim River Basin, and Junggar Basin. The development and utilization rates of water resources in the inner flow areas of these basins are as high as 15%, i.e., 4%, 112%, 91%, and 92%, respectively (Deng, 2018). Irrigation is a major constraint factor for agriculture. Agriculture accounts for a large proportion of the economic water use structure, and its utilization efficiency is low. Agricultural irrigation accounts for approximately 90% of the total water use. The coefficient of irrigation water use is low (0.3–0.4), and water resources are greatly wasted (Zhou et al., 2003). Therefore, the problem of the high water use in this area relates mainly to the lack of rational water use for agriculture. A fundamental way to solve this problem is to adopt efficient water-saving agriculture, which represents the development direction of modern agriculture. Adopting water-saving irrigation technology has become the fundamental way to achieve efficient water use in agriculture in arid areas, especially in arid oases. China has some experience and technology in realizing water saving and in utilizing and protecting water resources. For example, in the arid area of Xinjiang, agricultural efficient water-saving technology is highly valued (Ding, 2006; Zhang et al., 2017). During the "12th Five-Year" period, the promotion of water-saving irrigation technology constituted the main direction of efficient water use in oasis agriculture in arid areas. These technologies and experiences can provide a reference for Central Asia to solve similar problems and help it overcome the water resource crisis.

Table 3 Analysis of the annual water utilization quota in Northwestern China in 2015

Region	Annual water consumption per capita (m^3 person^{-1})	Farmland irrigation quota (m^3 mu^{-1})	Water consumption per 10000 yuan of GDP (m^3 (10000 yuan)$^{-1}$)
Nationwide	444	390	89
Northwest	936	505	183
Western Inner Mongolia	830	354	88
Northern Shaanxi	219	212	41
Northern Gansu	499	493	180
Northern Qinghai	323	311	33
Ningxia	971	727	223
Xinjiang	2446	588	619
Northwest/China (fold ratio)	2.11	1.29	2.06

Note: 1 mu is equivalent to 0.067 ha.

5.1 Canal seepage control technology

At present, the annual water consumption of China's agriculture is 386×10^9 m^3, accounting for approximately 70% of the total water consumption of the country. The irrigation water consumption is 356×10^9 m^3, accounting for 92% of the total water consumption of agriculture and 64% of the total water consumption of the country. The national irrigation water utilization coefficient is approximately 0.43, which is substantially lower than the level of 0.70–0.80 in Europe and Israel (Li et al., 2011). The average value of the water utilization coefficient of the national canal system is lower than 0.5, which is lower than that for other countries (0.78 for the United States, 0.61 for Japan, 0.6–0.7 for the former Soviet Union, and 0.58 for Pakistan) (Zhou et al., 2004). From the statistics, the annual water loss from the canal system in China is approximately 173×10^9 m^3, which is 45% of the total agricultural water consumption and 33% of the total national water consumption. As one of the most widely-used engineering water-saving technical measures in Northwest China, canal seepage control technology is effective for improving the water delivery capacity of pipelines and agricultural water-saving irrigation efficiency. Relevant research has shown that the average utilization coefficient of the canal system can reach 0.65 by adopting canal system seepage control technology. Experimental data from Shaanxi and Gansu provinces in Northwest China show that canal seepage control can increase the water utilization rate of the canal system by 20%–40% and reduce the canal leakage loss by 50%–90% (Lei et al., 2011). Canal antiseepage technology not only considerably improves the water utilization coefficient of the canal system, reduces canal leakage, and saves irrigation water, but it can also improve the safety assurance rate of canal water delivery, increase the anti-impact capacity of the canal, enhance the water and sediment delivery capacity, and reduce the channel siltation in water source irrigation areas with substantial sediment. After lining the canal, the velocity of the water in the canal is generally about one-third higher than that in the earth canal, and the diversion capacity of the canal is generally about 50% higher than that of the earth canal. Canal seepage control also has many other benefits, such as regulating the groundwater level, preventing soil from secondary salinization, reducing canal management and maintenance costs, and decreasing the size of canals and canal system buildings. Since the early 1970s, China has made great progress in canal antiseepage technology and its application. Some progress has been achieved in the development of new antiseepage materials and in the construction of new antiseepage technology, which play a core and important role in water-saving agriculture in China.

5.2 Water-saving irrigation technology using low-pressure pipes

Before the 1950s, the main irrigation technology in China was canal irrigation, but it occupied a large area and had poor water-saving performance. With the research and development of pipeline technology and the growing scarcity of water resources in Northern China, water-saving irrigation technology using low-pressure pipes was introduced. Low-pressure pipeline water-saving irrigation technology is a new type of surface irrigation technology in China. “Low pressure” refers to the working pressure at the outlet of the last-level pipeline in the field, which is inevitably lower than that of a microirrigation sprinkler or sprinkler, usually less than 3.0 kPa. A low-pressure pipeline irrigation system is mainly composed of a water source and intake system, a water distribution pipe network system, and a field water distribution system. In terms of the design, the working pressure of a pipeline irrigation system, it is required to be ≤ 0.2 MPa in hilly areas and ≤ 0.1 MPa in plain areas (Ma, 2018). Compared with the traditional water conveyance irrigation, this water conveyance irrigation technology can effectively reduce the leakage and evaporation in the process of conveying the water, increase the utilization coefficient of water conveyance to more than 90%, and ultimately save more than 30% of the water (Liu, 2011). At the same time, the pipe network system is mainly buried underground, which can effectively improve the land utilization rate. This technology has been developed from well irrigation areas to surface water irrigation areas in hilly areas. This water-saving irrigation technology generally has water-, land-, and labor-saving advantages.

5.3 Sprinkler irrigation techniques

The so-called sprinkler irrigation technology mainly refers to the pressurization of water in a water pump, so that the water is transported to the field through a pipeline at a certain pressure. Corresponding water spray nozzles are present in the field. Water is sprayed into the air above the field through the nozzles, forming small droplets that fall under the action of gravity. They are ultimately scattered in the farmland for irrigation. The sprinkler technology options can be divided into the following categories: Fixed-pipe sprinkler irrigation technology, central supporting shaft sprinkler irrigation technology, large-scale translational sprinkler irrigation technology, and spray irrigation technology with a corrugated disc. In recent years, the understanding of sprinkler irrigation technology has improved in Northwest China, and various improvements have been made, particularly through farmland practice. As a result, sprinkler irrigation technology has been optimized for crop growth, with good results. At present, more than 8.0×10^5 ha of farmland in China have used advanced sprinkler irrigation technology, confirming the benefits of sprinkler irrigation technology and securing its future development prospects.

5.4 Microirrigation technology

Microirrigation technology refers to irrigation in accordance with crop demands for water resources. It requires establishing a complete pipeline system, installing the corresponding emitters at the last level of the pipeline, and transporting the water and nutrients needed by crops to the field in specific quantities. The conveyed flow of materials is small and uniform, which can ensure efficient absorption by crops to reduce water use. In China, microirrigation technology has been developed and is mainly divided into surface microirrigation, underground microirrigation, microsprinkler irrigation, and spring irrigation technology. Compared with other water-saving measures, microirrigation technology has important water- and labor-saving benefits as well as strong adaptability to the soil, being able to adapt to the changes in complex terrain. However, on-going maintenance work is necessary to avoid problems in microirrigation systems.

5.5 Film hole irrigation techniques

Film irrigation technology is a new high-tech field of water-saving irrigation technology. The irrigation forms can be divided into film furrow, trickle film, and lattice field film irrigation. These technologies are generally used for plantings of specific crops, such as cotton, maize, and peanut, and have a good effect on the cultivation of melons. The water-saving effect of this irrigation technique is very good. Moreover, film irrigation technology is a local irrigation technology. Only the crops are irrigated, which greatly reduces the evaporation of water resources, achieves the efficient utilization of water resources, and ensures the efficient absorption of water resources by the crops.

These technologies are important for increasing the yield of grain and cash crops, which is mainly reflected in three aspects. 1) Increasing yield. Spray and drip irrigation can be timed to appropriately irrigate in accordance with the needs of the crops, thus harmonizing soil, water, air, fertilizer, and heat factors, promoting the growth of crop roots, spraying the leaves of the crops, and reducing stomatal obstruction, which is conducive to respiration and photosynthesis. It can increase the yield of common crops by 10%–30% and the yield of vegetables by several-fold. 2) Improving quality. Spray and drip irrigation can even greatly reduce the occurrence of fruit cracking. The rate of fruit increases from 50% to 90%, so the benefit of increasing income is enhanced. 3) Water saving: Spray, microspray, and drip irrigation save approximately 50%, 60%, and 70% of water usage, respectively. Meanwhile, they reduce several forms of labor, such as in irrigation, fertilization, disease prevention, insect control, and soil breaking and hardening, thereby reducing corresponding labor, fertilizer, and pesticide costs by 100–200 yuan mu^{-1}. They not only have great potential for reducing water use by farmland irrigation but can also promote the development of low-carbon agriculture in China. In general, these technologies have achieved effective results in Northwest China and other regions in recent years, mainly including improvements to water productivity, per unit yield, crop quality, disease and pest reduction, fertilizer use, power and energy use, production and labor costs, farmland conservation, and protection of the ecological environment. Agricultural water-saving irrigation technology thus has great potential. Popularizing and improving the utilization rate of irrigation water are effective ways for resolving agricultural water-use crises and dealing with the water shortages in Northwest China.

5.6 Rational allocation and regulation of water resources

The rational allocation of water resources is one of the control measures for effectively realizing the sustainable utilization of water resources in Northwest China. The allocation of water resources is the process of the redistribution and layout of water resources and their environment through human intervention. It has a good impact on the ecological environment and promotes the sustainable development of the economy and society, but can also lead to the deterioration of the ecological environment and affect the normal development of the economy and society. Water shortages are prominent in Northwest China, especially in irrigated areas. The water and soil resources in irrigation areas are unevenly distributed, the limited water resources lack unified allocation, and water source projects cannot fully execute their roles. Therefore, limited irrigation water should be distributed reasonably in time and space to improve irrigation efficiency in the northwestern area. Technology for the rational allocation of water resources in Northwest China have mainly been developed from two aspects: the regional development level, and the development and utilization level. The effective utilization of water resources can be achieved by optimizing the structural system of shelterbelts by combining them with trees, shrubs, and grasses, and by combining forest belts, forest networks, and pieces of forests. At the same time, the western route of the South-to-North Water Transfer Project, regional water transfer projects, runoff regulation and storage, and tributary reservoir project technology (reservoir water storage, channel drinking water, lift irrigation, etc.) are key technologies for realizing the reasonable space-time distribution of water resources. These technologies can improve regional water source conditions, realize the rational matching of water resource utilization, and achieve economic development. The rational distribution of water use proportions in the upper, middle, and lower reaches of the basin and the establishment of a reasonable regional distribution scheme are also effective ways to improve the utilization rate of water resources.

6 Sand prevention and control technology

Desertification has become one of the most important global ecological environmental problems. Desertification control is the ecological guarantee of the “one belt and one way” strategy. The SR Economic Belt is a vast area that runs through Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang in Northwest China. This region has a dry climate and sparse vegetation, 95% of the country is desertified, and the land desertification is severe. Kazakhstan, Uzbekistan, Kyrgyzstan, Turkmenistan, and Tajikistan in Central Asia are also regions with serious desertification. The excessive use of artificial irrigation water, deforestation, overgrazing, and grassland degradation have eventually led to serious desertification.

China has long been actively studying various countermeasures and measures to prevent and control land desertification. Taklimakan Desert, located in Northwest China, is the largest desert in China and the second largest mobile desert in the world. It is a significant representative in the field of desertification control in China and even in the world. Kubuqi Desert, located in the arid area of Northwest China, is the seventh largest desert in China and it is the only desert globally that has been successfully regreened. There have been many successes in terms of management technology, including general sand fixation and afforestation, mechanical sand barriers, and other new technologies. Some notable examples include the agricultural technology of closed greenhouses in arid areas, drip irrigation technology, and the application of chemical measures, such as water absorbents, water-holding agents, and sand-fixing agents.

6.1 Plant sand fixation technology

In Northwest China, plant sand control technology is an effective and durable biological measure for slowing the further expansion of desertification. In the application of plant sand fixation technology, the selection, introduction, and cultivation of forest and grass species are important conditions for successful vegetation ecological construction. Continuous social practice has shown that in the arid and semiarid areas of Western China, most of the effective sand-fixing plants are perennial shrubs, semishrubs, and some herbs with strong vitality. In general, *Haloxylon*, flower stick, overlord, *Elaeagnus*, *Tamarix*, *Nitraria*, hairy strip, and other sand shrubs are regarded as effective. Only through the proper selection of perennial shrubs, subshrubs, and some herbs with strong vitality can we further improve biological diversity, promote efficient plant sand fixation engineering, prevent desertification, and enhance the quality of the ecological environment. The popularization and application of plant regeneration sand barrier technology have further expanded sand prevention and control applications, transforming mechanical sand barriers into plant sand barriers for comprehensive sand control, and they have also addressed issues relating to the fixation of wind erosion, sand burial of mobile sand dunes and plant survival and preservation. Sand-based plants with strong germination ability have been used as sand barriers, and they can be buried in the sand, inserted into a drill pipe, or laid for cutting so as to promote the self-renewal and reproduction of the vegetation. Poplar and willow are planted with a new low-pressure water-flushing method, which saves labor costs and also greatly improves the survival rate of plants supplemented with water. Water bottle afforestation technology is also widely used. Poplar stubble is inserted into a glass bottle filled with clear water, which is then planted in the sand. The survival rate of water bottle afforestation plants is 100% after one year, which is more than twice the rate of conventional afforestation plants.

6.2 Afforestation technology on windward slopes

Afforestation on windward slopes is a highly efficient afforestation technology that has been explored in the control of Kubuqi Desert dunes. Sand dunes can be fixed by planting *Salix psammophila*, flower sticks, and other shrubs with strong resistance to wind erosion and high sand fixation capability on the windward slopes of mobile sand dunes or by afforestation to directly reduce the wind speed. In the lower part of a leeward slope to the foot of a hill and the lowland among hills, arbors or mixed forests of tall willow, poplar, and camphor pine are planted to block the flow of sand dunes. This afforestation technology utilizes the dynamic characteristics of wind erosion of the mobile dunes to fix those mobile dunes and gradually reduce the height of the dunes. Depending on the natural forces, the desert land can be flattened in 4–5 years, and the afforestation cost can be reduced. For example, in an afforested 6253 km^2 desert, this technology can reduce the amount of land-leveling work by approximately 12×10^9 m^3 and save nearly 30×10^9 yuan in cost.

6.3 Water vapor method tree planting technology

The water vapor method is the main planting technology used in Kubuqi Desert. It is suitable for aeolian sand or flowing aeolian sand and for cutting trees. It uses groundwater (a well) as the water supply source and a diesel engine as the power source. The water is pumped using a 3-inch centrifugal pump and divided into several streams in accordance with the installation of a diversion device at the outlet of the water pressure pump. Each stream is connected to a hollow steel pipe with a length of 1.5 m and a diameter of 2–3 cm through a plastic hose (its length can be adjusted in accordance with the distance from the water-consumption point to the water well). In the afforestation process, a hollow steel pipe is used as the impact water gun. Water is directly injected into a sand dune through the pressure of the water pump to form a planting hole, and a seedling is then inserted into the planting hole. The sand around the seedling is flushed into the gap with the water gun until the hole is filled and sealed, and the afforestation process is completed one seedling at a time. It is a new technology that combines planting and irrigation, which is a revolutionary change in desert control technology. The planting speed has been greatly improved. On average, one *Salix* tree can be planted every 30 s. Each person can complete more than 5333.36 m^2 of afforestation area every day, which is 14 times greater than that via traditional excavation planting. The survival rate of seedlings exceeds 90%, and the preservation rate reaches more than 80%. The cost of sand control is also greatly reduced by this method. Once the planting is completed, the seedlings can also be protected without a separate sand barrier to prevent death caused by wind erosion. The key technologies of this method include water source preparation, seedling preparation, and program control.

6.4 Soil improvement technology

Glycyrrhiza uralensis grows rich rhizobia in the desert, which have an excellent soil improvement effect. After planting *G. uralensis*, the soil nitrogen content of the cultivated layer was found to increase considerably by 38%, 76%, 110%, and 148% in the first four years. It has a notable improvement effect on sand, can remarkably reduce the soluble salt content of surface soil by more than 80%, and is an effective plant for desertification control. *Glycyrrhiza* desert control technology refers to the use of a "translational planting method" to grow *Glycyrrhiza* horizontally. The green desert area of a *Glycyrrhiza* plant is expanded from 0.1 m^2 to 1 m^2, and this new technology has increased the greening effect by 10-fold. Licorice planted using the translation method can also avoid large-scale damage to the soil during excavation. With this new technology, four goals have been achieved simultaneously: greening of the desert, establishing the licorice industry chain, repairing the land, and poverty alleviation.

6.5 Composite sand barrier technology for plant engineering measures

Composite sand barrier technology, i.e., the application of plant and engineering sand fixation measures, is the characteristic sand barrier technology used for sand prevention and control in Kubuqi Desert. Research has shown that a sand barrier will intercept approximately 75% of the sand volume in the early stage. Regarding wind speed, in a low-wind-speed sand area, a stone grid or geogrid fence with a good wind fixation and windproof effect is used; while in a moderate wind erosion sand area, cluster planting is used to realize sand fixation with strong wind erosion resistance; and in a strong wind erosion area, biological measures are considered in combination with mechanical sand barrier measures to improve the sand fixing efficiency. In a general sand burial area, plant species with a strong germination capability and rapid growth are selected; while in an area of strong sand burial, high vertical mechanical sand barriers are chosen over planting measures to fix the sand. In the composite sand barrier technology, biological sand fixation is the fundamental measure, and engineering measures are mostly used as auxiliary measures to protect the plant species from sand damage in the early stage of growth.

In accordance with the characteristics of wind sand hazards in the Kubuqi Desert, a new technology combining engineering sand barriers with biological sand fixation has been developed in recent years. Low vertical small-grid sand barriers (1 m×1 m or 1.5 m×1.5 m grid sand barriers with a height of 20 cm), high vertical large-grid sand barriers (a 3 m×3 m grid sand barrier with a height of 50 cm or a 5 m×5 m grid sand barrier with a height of 110 cm), and other engineering sand barrier technologies with different specifications have been established, such as net pile-combined sand barrier and sand surface covering net using HDPE nets and plant fibers. With the planting of *Salix*, *Artemisia*, *Shami*, and other sandy shrubs and herbs, the regular monitoring of vegetation restoration, sand transport, and surface erosion accumulation changes should also be considered.

6.6 Comprehensive sand fixation forest protection technology

In areas with serious sand damage, suitable tree species and layout modes have been chosen in accordance with the different types of sandy land. The comprehensive sand fixation forest protection technology mode, which is composed of windbreak sand fixation forest, forest and agriculture composite sand fixation forest, and sand fixation feed forest, has become the basic set of treatment measures. In addition, sand sealing and afforestation have become important components of sand control technology in China's national defense, reaching leading levels internationally. Based on front pulling and back retaining, the integrated sand control and river protection engineering technology of arbor, shrub, grass, and algae can be created, and an effective ecological barrier area can be formed by combining and inserting *Salix*, sowing *Artemisia*, and planting *Salix*.

7 Ecological control technology for saline-alkaline land

The main reason for the decrease in the area of the salt water lake located at the junction of Kazakhstan and Uzbekistan in Central Asia is that a large amount of water was introduced into the lake for irrigation, which intensified the soil salinization in the surrounding areas. Uzbekistan is a country with relatively high chemical fertilizer application intensity and soil salinization. In China, Xinjiang is located in the core area of the SR Economic Belt, and it is regarded as the world's salt and alkali museum. However, soil salinization has seriously hindered the sustainable development of agriculture in this region and has affected the stability of the ecological environment of the oasis. China has made significant advances in the ecological management of saline-alkaline land. Owing to the strong similarities of climate, soil, and hydrology between Central Asia and Xinjiang and Inner Mongolia (the Hetao Irrigation Area), some successful approaches can be used as references to address the similar ecological problems in Central Asia.

7.1 Technology for the improvement of water conservation engineering

Technology designed for the improvement of water conservation projects is the premise of soil salinization. Only by improving water conservancy can the irrigation and drainage system be improved, thus allowing other measures to play a role. In accordance with the different conditions of irrigation areas, the canal system, spray drip irrigation, and well irrigation engineering technologies are usually used to improve saline-alkaline land. Simple plastic film hose technology for water conveyance irrigation is an important supporting technology for implementing water-saving irrigation, reducing the rise of the groundwater level, and preventing the secondary salinization and swamping of soil in saline-alkaline land. The horizontal drainage is mainly in the form of open ditches and concealed pipes, in which the Dutch concealed pipe drainage technology is one of the most effective methods used to control saline alkali land. Underground drainage consumes minimal arable land, reduces the need for bridges and culvert buildings, provides convenience for mechanized farming, effectively decreases the groundwater level, and improves the physical environment of the arable soil. Applications of these technologies in practice have proven that the underground drainage soil desalination effect is good, the drainage amount is large, the management cost is low, and the production increase is remarkable. Compared with open channels, planting areas can be increased by 12%. The vertical drainage is mainly accomplished through shaft drainage and irrigation.

7.2 Physical and agricultural improvement technology

Physical technology for saline alkali land improvement mainly includes flat land preparation, rational cultivation, elimination of salt spots, and removal of topsoil. Deep ploughing and ridge drying technology loosen the surface layer and also transform the saline-alkaline land to alter the distribution of salt in the soil profile. The technology used for improving the guest soil mainly involves digging an alkali spot deep within a heavy alkali spot plot, backfilling with the guest black soil, providing suitable soil conditions, and avoiding the influences of restrictive factors on vegetation restoration. Deep straw combined with surface straw mulching technology can inhibit salt accumulation on the soil surface, reduce the stress from soil salt on crop growth, decrease the return of salt to the soil arable layer, and ensure the normal growth of crops. The technology of sand spreading and alkali pressing is one of the main technical means to improve saline alkali soil. It changes the soil structure, promotes the formation of aggregate structures, increases the soil porosity and permeability, modifies water and salt movement in saline alkali soil, enhances the water conservation and storage capacity of the soil, and reduces the evaporation of soil water to inhibit the upward movement of salt in the deep layer. The alkalinity of the topsoil is reduced; hence, it plays a role in alkali reduction.

7.3 Chemical and biological improvement technology

Chemical improvement techniques include the application of gypsum, phosphogypsum, superphosphate, humic acid, peat, and vinegar residue. Sepiolite has been used in several areas to improve saline alkali soil, and it has achieved good results. Biological improvement technology mainly includes the selection of salt-tolerant crops, the use of effective microorganisms, the application of organic fertilizers, and the planting of *Artemisia salina*, Sudan grass, and other plants with strong fertility and rapid growth, in addition to planting some green fertilizer crops to absorb the salt. A comprehensive biological and chemical improvement technology, such as the application of soil improvers, biological complexation, and displacement reactions, removes the excess ions in soil particles to improve the soil quality. The above technology has been shown to provide remarkable economic and ecological benefits.

8 Conclusions

The construction of "OBOR" is not only a major national strategy of China but also an important platform for the common development and cooperation among all the countries along the line. The ecological environment throughout Central Asia and most parts of Northwest China is generally fragile and also sensitive to global climate change. With the implementation of the strategy of "OBOR" construction, human activities in these areas have obviously intensified, and the pressures of industrialization and urbanization on the ecological environment have been significantly enhanced. The ecological threats they pose cannot be ignored. Every country needs to jointly act to build an "OBOR" ecological civilization. The protection and control of the ecological environment, especially in Northwest China which is the key area of the SR Economic Belt, are of great significance to the success of its construction. Therefore, we have summarized the key technologies in accordance with the major ecological control projects under the "OBOR" strategy, aiming to strengthen the scientific allocation and efficient utilization of water resources and the desertification control in the areas all along the "OBOR".

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一带一路视域下的干旱半干旱区生态治理技术研究

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摘 要：在经济全球化高速发展的人类命运共同体新时期，“一带一路”的建设需统筹生态环境保护和经济开发二者关系。然而，21 世纪丝绸之路的沿途国家，绝大多数都还是发展中国家，目前大都面临着与中国相同或类似的生态与发展困境。在本文中，我们以全球气候类型分布为基础，筛选同属于温带大陆性气候的中亚地区和我国西北地区作为研究对象，通过文献分析法、对比分析法等对我国西部地区和中亚地区在“一带一路”发展过程中所面临的主要生态问题进行了梳理与总结，同时结合近几年实施的重大生态治理工程，提出有关水资源利用与保护、防沙治沙、盐碱地治理等具有一定可推广性的生态治理关键技术，旨在为“一带一路”沿线地区和国家打造生态治理体系提供技术模式的经验和参考，为各国实现绿色发展、加强全球生态治理提供新思路，对完善全球发展模式具有重大意义。

关键词：一带一路；生态文明；生态治理；生态治理技术