

REVIEW

# Desertification: China provides a solution to a global challenge

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**Abstract** Desertification has been caused by various factors and is a major environmental problem and development bottleneck faced by the world. It is also a serious threat to ecological security and to sustainable economic and social development. As a stubborn world problem, focused on by the United Nations 2030 sustainable development goal 15.3, China aims to combat desertification by implementing the “eight-column four-beam” strategy, and also suggest the “four-medicine” approach for global desertification governance. This includes the development of the United Nations Convention to Combat Desertification protocol, unified global compliance and compliance metrics; building a global observation network, and monitoring land changes based on remote sense; preparing the global natural desert (heritage) list, leaving the original deserts for future generations; initiating the global action of combating desertification, and striving to achieve a land degradation-neutral world by 2030.

**Keywords** desertification, global governance, land degradation neutrality, LDN, origin, status, strategy, sustainable development

## 1 Introduction

Land desertification is one of the major global challenges that threaten human survival and sustainable development. In fact, over two-thirds of countries and regions, one-fifth of the worldwide population and a quarter of the entire land area are suffering from desertification, which is expanding at a rate of 50000 to 70000 km<sup>2</sup> per year. China is one of

the countries most threatened by desertification, where desertification has led to land degradation, to deterioration of the ecological environment and to increased natural disasters and frequent dust storms. Furthermore, annual desertification issues in China have caused huge ecological and economic losses, accounting for over 64 billion CNY in direct economic losses each year. Meanwhile, nearly 400 million people have been directly or indirectly affected by desertification problems. In short, this issue is seriously restricting China’s ecological security and sustainable socioeconomic development.

Nonetheless, over the past 60 years, the battle against desertification in China has achieved steady progress following continuous evaluation. In particular, ecological conditions have significantly improved in Aeolian sand areas. In fact, compared to 2009, the area of domestic desertified land and sand areas showed a twofold reduction in 2014.

## 2 Previous generations and current views on desertification

### 2.1 Recognition of desertification

Desertification has been defined as “the land degradation through the process of climatic variation and human activities in arid, semi-arid, and dry sub-humid areas” (UNCCD, 1994). In fact, the term *desertification*, comes from the French *désertification*, which was first used in 1927 by a French naturalist and forester, Lavauden. The term was next used in 1949 by Aubreville, another French botanist and forester, in the book entitled, *Climate, Forests and Desertification in Tropical Africa*. However, the concept remained known only to a small number of ecologists, botanists, foresters and phylogeographers at that time<sup>[1]</sup>.

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In 1949, Aubreville described desertification as the process of changing productive land into a desert through soil erosion and other destructive human activities. In the same year, when he studied soil erosion in the wet tropics of West Africa, he found that the forest boundaries had retreated between 60 and 400 km due to deforestation and fire. The forest became a tropical steppe, with marked soil erosion, physical and chemical changes and an increase in the spread of xerophytes. This book also posited and defined the term, *savannization*, as the decay of tropical and subtropical forests on the African savanna, with man-made fire and deforestation given as the main causes of this phenomenon. Throughout this work, Aubreville continued to use *desertification* to describe how this phenomenon had become highly developed. Since then, Le Houérou<sup>[2]</sup> also proposed the term *desertization* and defined it as, “a typical desert landscape and land form that has not expanded to the area recently without desertification.” He then continued to explain how “desertification occurs at the edge of the desert with an average annual rainfall ranging from 100 to 200 mm in the arid area.” However, these terms were not widely recognized by the academic community at that time<sup>[3,4]</sup>.

Among the most notable examples of desertification, those that have perhaps left the largest imprint on our memories, is the American Midwest dust storm of the 1930s, which was subsequently called the Dust Bowl. Elsewhere, the extreme drought experienced in the Sudanese-Sahelian region of Africa during 1968–1973 transformed a large area of grass, shrubs and trees in north Sahel into a *pasture of death*. Grazing was seriously restricted after many shallow and seasonal wells dried up. Thus, an ever increasing number of hungry animals concentrated on the area near the water supply and threatened the capacity of the grassland, such that the vegetation and the soil were left severely degraded. When some livestock herdsmen let their grazing animals move to the south to look for good pasture, they left behind an area of seriously degraded land. Due to the extreme levels of grazing, these land patches resembled a skin disease which extended outwardly, gradually connecting the pieces, and this led to the impression that the Sahara desert was moving southward. Furthermore, some southern countries were also affected by the drought, to the point where they could not provide adequate living conditions for the immigrants from the north and the viability of these countries remains a problem.

In fact, the drought lasted for years and resulted in poor harvests, pasture degradation and depletion of water resources, which, in turn, led to a large number of deaths among both the livestock and the people. Indeed, it was estimated that the total number of human deaths during the drought period numbered somewhere between 50000 and 250000, while the number of livestock deaths was estimated at several million. In fact, according to United Nations Food and Agriculture Organization (FAO)

estimates for 1972–1973, the number of cattle that died that year was about 3.5 million<sup>[5,6]</sup>.

In 1974, the International Geographic Society organized a symposium on desertification where they discussed its definition and causes. Following this, an academic conference on the processes, problems and perspectives of desertification was conducted by the University of Arizona in 1975. These events significantly raised public awareness of desertification. Indeed, during this period, many scholars undertook primary research on the composition and causes of desertification. While the area of study was limited to the Sahel in Africa and the reports contained widely differing opinions on certain issues, these activities nevertheless laid a foundation for future research.

In 1977, facing the increased severity of desertification, the United Nations convened the United Nations Conference on Desertification in Nairobi (UNCOD). More than 500 representatives from 94 countries, regions and international organizations attended in order to scope and analyze desertification comprehensively and scientifically for the first time. During this meeting, a map (1:25000000) of desertification was presented, having been compiled by the FAO, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Meteorological Organization and the United Nations Development Programme. In addition, an initial assessment of the global desertification status was made. The General Assembly also developed the United Nations Plan of Action to Combat Desertification and resolved to take international action to prevent desertification and to assist in the economic development of affected areas. This conference significantly motivated global research on desertification and its prevention. It thus signified an important milestone in the history of the study of desertification and the meeting alerted the world to the seriousness of desertification, and to how its prevention and control were urgently needed<sup>[7]</sup>.

The United Nations regards human activities as the main cause of dry land degradation. Undoubtedly, the process of dry land degradation is complex, however, it is inconceivable that there is no official definition of dry land. The United Nations has published the outcomes of discussions on the concept of desertification, the geographical distribution map of the Budyko-Lettau Drought Index and the UNESCO world dry land distribution map. The United Nations also emphasizes that desertification does not have any causal relationship with naturally-occurring desert and that it can occur on other reclaimed land.

## 2.2 Different voices

The United Nations Conference on Desertification was intended to address the social and economic problems caused by the drought in Sahel. However, in reality, it led to more than 10 years of dispute over the meaning of desertification, because this word appeared in the name of the conference. In fact, Dregne said dramatically in 1983

that this event was the culmination of the effort of political genius. Here, we quote the definition posited by Dregne at this meeting in order to compare it with the other definitions:

*Desertification refers to the ecosystem depletion in arid, semi-arid and some sub-humid areas, which is caused by human activities and drought. The changing processes of these ecosystems can be expressed and measured by the determination of the decline in plant productivity, the change in biomass, the difference between the tiny and huge size of fauna and flora, the soil degradation, and the increased harm to humans.*

We can see that this definition emphasizes the occurrence of desertification and its driving factors by noting that desertification is essentially a degradation of ecosystems in terms of land productivity decline, changes of flora and fauna and soil degradation. Subsequently, however, the first World Desertification Map produced by the FAO used a revised definition of desertification:

*Desert expansion could cause a decline process in biological production capacity; the result may decrease the plant biomass, land carrying capacity, crop yields and affect human health.*

Their mapping of desertification areas includes extremely arid, arid, semiarid and semihumid areas.

In the above definitions, changes in landscape and the decline in land productivity were emphasized, while there is no limitation place on the area susceptible to desertification or on its drivers. After 1977, scholars from all over the world carried out extensive research on desertification, which deepened the understanding of the phenomenon. Furthermore, in order to continue to strengthen the study of the Sahel, the study area has expanded from regions to continents, even to the entire world. However, the debate on the definition of desertification continues, and many scholars define desertification according to their different professional backgrounds and regional contexts. In terms of research focus, deeper and more meticulous research on the causes of desertification involves the influencing mechanisms arising from natural and human factors during the desertification process, in addition to the formation mechanism, evaluation and dynamic assessment of desertification.

In exploring and researching assessment and mapping methods of desertification, the FAO and United Nations Environment Programme (UNEP) proposed a further definition of desertification:

*Desertification is a combination of economic, social, natural and other multiple factors in a dry climate and/or arid soil area, it breaks the natural balance among the soil, vegetation, the atmosphere and water, and continues to get worse, which may cause the decline or destruction of the biological potential of the land, the deterioration of the living environment, as well as the increase in the desert landscape.*

In 1993, biodiversity was added to the definition of

desertification by the FAO as follows:

*Desertification has led to a recession of the physical, chemical and biological potential in arid and semi-arid areas and threatens biodiversity and human survival; the origin cause is a collection of geography, climate, biology, and human factors.*

For their part however, Warren and Agnew concluded after reviewing the existing relevant definitions that the definition of desertification does not include a strict distinction between desertification (which can lead to desert) and land degradation (reducing productivity without causing desert). In fact, they regard desertification as a process that will lead to desert landscapes or as a functional process that may cause the productivity degradation of desert systems, or as both. They argue that even sparse vegetation (lower biological productivity) may be richer in nutrients with a better palatability for livestock than high-yielding vegetation. Therefore, for them productivity is not an effective indicator: the desertification must lead to a permanent degradation, while the vegetation degradation should be serious enough to indicate desertification<sup>[7,8]</sup>.

Although the international community has numerous and varying definitions of desertification based on their respective duties, the term, desertification, and its attendant translations continue to be controversial within academia. In fact, the focus of the debate can be summarized as including the following aspects.

(1) **Definition.** While the term desertification must exist from an academic point of view, at present, many experts think the word lacks scientific rigor and that its definition is the result of political compromise. In short, its purpose is to ensure the countries affected by land degradation receive long-term economic aid from donors. In fact, the current definition of desertification appears absolutely equivalent to land degradation in arid, semi-arid and dry subhumid areas. However, it can be argued that land degradation is not the same as desertification, which has far more emotive overtones.

(2) **Time scale of desertification.** Although desertification is seen as land degradation in a certain area, the problem of the basis of comparison (or benchmark) for its occurrence over time cannot be avoided, because desertification implies that the process has already happened in an area compared to some moment in the past. Some scholars use the geology time scale to define the occurrence of desertification. Thus, for them the deserts formed in the geological age are definitely desertified land. However, other scholars put forward the clear idea that desertification has occurred in the time of human history, because only when human beings appeared was the land seen as a terrestrial biologically-productivity system, whether or not degradation of the land is due to human utilization. For instance, in 1984, Henry Lahoru identified that desertification has happened within the last 3000 to 6000 years. However, the United Nations action plan for combating

desertification continues to refer to a decades-long scale for evaluating desertification.

(3) **Spatial scale of desertification.** While most domestic and foreign experts agree that desertification occurs mainly in arid, semi-arid and in parts of subhumid arid areas, other scholars, such as Mabbutt and Meckelein, suggest that the areas should also include deserts and extremely arid areas. Meanwhile, a small number also suggest that wet areas should be included, as desertification could occur anywhere on earth<sup>[9]</sup>.

(4) **Criteria for desertification.** Desertification is generally considered as the process of land degradation in a particular area as well as the final result of land degradation, or the synergies between the process and result. However, even if desertification is recognized as the process of land degradation, the question remains: how to measure the intensity and degree of degradation and desertification, and which indicators will be measured. By contrast, if the desertification is seen as the final result of land degradation, meaning this land has completely lost productivity or has suffered irreversible degradation, the matter becomes one of how to evaluate the flexibility of the land.

(5) **Cause of desertification.** Climate variation and human activities are two main causes of desertification according to the convention. Here, human activity mainly refers to the unreasonable use of natural resources for the development of human civilizations, for urbanization, industrialization and wars. In fact, most scholars maintain that human activity has been the greatest factor affecting desertification since the first human societies formed. However, the question remains as to what role climate variation (or climate change) has and what role drought has during land desertification. These problems are still important to both academics and to human society as a whole, especially since the extreme drought in the Sahel occurred. Indeed, following the United Nations conventions on climate change and biological diversity, more scholars have been encouraged to focus on climate change, drought and desertification.

(6) **Determining the trend of desertification development.** At present, we are unable to determine the speed of desertification and its attendant trends due to a lack of data from a sufficiently long time series of observations of the climate, soil, vegetation and other data related to land desertification. For example, in terms of vegetation migration in the Sahel, Africa, it was found that the local vegetation boundary can migrate south by 5 to 6 km·yr<sup>-1</sup> in the dry season and moves back the same distance in the wet season. Nevertheless, it is impossible to detect the regularity of this phenomenon due to the lack of satellite images and ground survey data prior to the last 30 to 40 years.

(7) **Solution to desertification.** Desertification is an environmental problem concerning the whole of society and also a serious social problem with a far-reaching

perspective. The problem remains one of finding solutions to the questions of whether to protect and restore the land through the existing technologies, whether to make the reasonable use of land come under a judicial system and a tax system or to improve existing international relationships through the external assistance of more developed countries. In practice, the convention is, to some extent, a kind of collaboration within the international community<sup>[7]</sup>.

### 2.3 Agreement on terminology and definition

For certain, the controversy is far from over and action is urgently needed. However, after experiencing the establishment, controversies and amendments to the term and its attendant issues, the 1992 United Nations Conference on Environment and Development finally included climate variability as one of the causes of desertification. In fact, they finally settled on the definition of desertification in Agenda 2 as follows:

*[Desertification] means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 1994).*

Meanwhile, this definition was adopted in 1994 by *The United Nations Convention to Combat Desertification in those Counties Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD, 1994)*. So it appears that the controversy regarding the definition of desertification has been brought to an end, at least temporarily, and all dissent is now reserved to scholarly discussions.

The definition identifies three factors. First, desertification is produced and developed by a variety of factors, including climate variation and human activity. Second, desertification occurs in arid, semi-arid and subhumid arid zones (the ratio of annual precipitation to potential evapotranspiration is from 0.05 to 0.65, excluding the polar and subpolar regions), which posits the occurrence of conditions and the distribution of desertification. And third, desertification is land degradation that takes place in a wide region which comes under the framework of the global land degradation. This means that the definition has defined the coverage area of desertification<sup>[7]</sup>.

Following the convention, land is now defined to encompass its ecological system with biological productivity, including the soil, vegetation and other biota and their service to the ecological and hydrological processes in the land system. Meanwhile, degraded land now refers to the decline of biological or economic productivity and to diversity loss, due to one or several factors in using irrigated land, pasture, forest and grassland, in arid, semiarid and subhumid rain regions. This definition includes the following notions. Soil loss is caused by wind erosion and water erosion, the physical, chemical and biological characteristics or the economic values of the soil

have depreciated, and there is a long-term loss of natural vegetation.

At this point, the consensus on the concept of desertification has reached global agreement, which facilitates the assessment of desertification and the cooperation in combating desertification worldwide. Indeed, following the convention, it is agreed that there are four basic processes that lead to desertification: wind erosion, water erosion, salinization and freeze–thaw erosion and China's desertification is due mainly to sandy desertification, soil and water erosion, soil salinization and freeze–thaw desertification.

#### 2.4 New targets for land degradation neutrality

At the UN Sustainable Development Summit held in New York on 25 September 2015, some 193 UN member-states officially adopted 17 sustainable development goals (SDG). These SDGs aim to comprehensively change the ways of solving social, economic and environmental development problems, transforming them into a completely sustainable development path from 2015 to 2030. For example, SDG 15 was proposed to ensure the following:

*The conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their service, to sustainably manage forests, combat desertification, halt and reverse land degradation and to halt biodiversity loss*<sup>[10]</sup>.

in which, the SDG target 15.3 aims to:

*...by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world*<sup>[11]</sup>.

### 3 China's strategy and actions to combat desertification

The Chinese government has made remarkable achievements in combating desertification and has accumulated considerable experience, including adherence to government leadership, significantly contributing to the solution of ecological programs, encouraging people to participate widely in social forces for desertification control, giving more attention to scientific desertification technology and fully using modern technology, giving attention to a combination of prevention, control of desertification, and utilization of resources in Dryland, and adhering to the laws and regulations, emphasizing the legal guidance and policy incentives in desertification combating.

#### 3.1 Government leadership

The Chinese government provides leadership in the long term prevention and control of desertification. Through planning, setting up responsibilities and establishing

projects, China's national desertification control work has been undertaken in an orderly way.

##### 3.1.1 Planning and programming

The Chinese government has formulated and implemented a series of programs related to combatting desertification and proposed corresponding strategic objectives and priorities, such as the National Master Plan on Key Functional Areas (2010), National Outline of the Overall Plan for Land Use (2006–2020), National Ecological Protection and Rehabilitation Plan (2013–2020), National Master Plan for Sand Prevention and Control (2011–2020), National Desert Park Development Plan (2016–2025), Three-North Shelterbelt Project (1978–2050), Beijing and Tianjin Sandstorm Source Control Project (2000–2020), and Grain for Green Project (2000–2020).

##### 3.1.2 Construction of institutions and their responsibilities

###### (1) Organizations and institutions

The Chinese government set up the 19 ministerial member board of the China Coordination Group to Combat Desertification. To implement the UNCCD as a member of the inter-ministerial coordination mechanism, the departments will, in close coordination, undertake collaborative research to solve desertification control work on the major issues. Among these, as the lead units, are the State Forestry Administration, the specific units for prevention and control of desertification management center (desertification control office), unified management of the national prevention and control of desertification. China's desertification control organization has formed the coordination and management system led by the forestry sector, from central to local, including multilevel and cross-domain sectors.

At the same time, in order to better promote national desertification control research, technology and performance ability, the Chinese government has also set up a range of institutions, Chinese Desertification Monitoring Centre, China National Sand Control and Desert Industry Society, Chinese Desertification Control Training Centre, Chinese Desertification Research and Development Centre, Institute of Desertification Studies of Chinese Academy of Forestry, National Committee for Sand Control Technology Standardization, and Chinese Desert Ecosystem Positioning Research Network.

###### (2) Local responsibility system

In 2009, in order to ensure the implementation of national desertification control policy, the central government and the provincial government signed the desertification control responsibility target, the prevention and control of desertification responsibility target, and assessment work agreement combined with the agreement for the implementation of the national plan for the prevention and

control of desertification. Every 5 years, a period of assessment is to be conducted. At the same time, led by the competent departments of the State Council, serious desertification of provinces will be regularly inspected and the State Council will supervise the completion of tasks.

In 2011, seven ministries jointly launched the provincial government comprehensive assessment under the Eleventh Five-Year Plan. In 2012, after the State Council approved the publication of the 12 provincial and municipal assessment results, the provincial government signed the Twelfth Five-Year Plan (2011–2015) target with responsibility to promote the prevention and control of desertification. In 2016, six ministries assessed the provincial government target responsibility during the Twelfth Five-Year Plan.

### 3.2 Public participation

#### 3.2.1 Voluntary tree-planting

Voluntary tree-planting means that the citizens of a suitable age prepare land, raise seedlings, plant trees, provide protection and perform other land-greening tasks, or other work related to the purposes of land-greening.

In 1981, the Fifth National People's Congress of the fourth meeting passed a resolution to conduct a nationwide voluntary tree-planting campaign. In 1982, the State Council issued the measures for the implementation of a nationwide voluntary tree-planting campaign; all the citizens of the People's Republic of China, males 11–60 years old and females 11–55 years old, should undertake unpaid voluntary tree-planting tasks<sup>[11]</sup>.

Since the development of a comprehensive voluntary tree-planting campaign across the country, which actively organized citizens, the establishment of demonstration bases, all combined with the actual local ecological construction, emerged to undertake voluntary tree-planting activities in various forms. Every year the leadership at all levels of party and state leaders set the example and participate in voluntary tree-planting activities. This provides role models for school-age children to fulfill their obligation to plant trees. Every year since 2002, the ministers of the Republic have participated in voluntary tree-planting activities under this scheme<sup>[12]</sup>.

#### 3.2.2 Public-private partnership

In China, private enterprise has an important role in controlling desertification as well as in industrial development. In Inner Mongolia, for example, the Elion Group has emerged as a company that has joined in the prevention and control of desertification.

Elion Resources Group, which was formed in 1988, is committed to the Kubuqi Desert Ecological Construction

and has nearly 30 years of experience. Since 2007, meetings have been held every 2 years in the Kubuqi Desert to expand the international forum of China's private enterprises participating in managing sandy land. In May 2011, Elion established a public welfare foundation. The desert green economy will receive annual investment funds to support the practice and promotion of sustainable development. Elion created a set of ecological constructions, industrial developments, community developments and many areas of culture and education for integrated public and private partnership.

Shaanxi Guangyin Shi enterprise which focuses on sand control is a typical successful enterprise developed from individual sand control experience. Guangyin Shi is a famous hero in combating desertification in China. He founded the first farmer's company. The company relies on "governance, overall strategic development and utilization of sandy land" and improved the ecological environment and sustainable economic and social development to provide a new path.

In addition, in Inner Mongolia, Xinjiang, Qinghai, Ningxia, Gansu and other north-western regions, there are still many enterprises that develop sand-control industry, contributing to regional desertification control and the development of the ecological economy.

Non-governmental organizations (NGOs) have also been involved in the prevention and control of desertification in China, such as the Chinese Civil Power Sand Control and Sand Industry Association, the Inner Mongolia Association of Desertification, the Alashan SEE Ecological Association, and agencies in Shenmu County, Shaanxi Province Ecological Association as the representative of the group from simple publicity, development financing the implementation of desertification control project<sup>[13]</sup>. Foreign NGOs also actively participate in the work of prevention and control of desertification in China, for example the Japan Obuchi Fund, the World Association of Japan, Japan Desert Greening, South Korea's future forest, and ecological peace in Asia. China Cultural Association adolescents also have, through field project cooperation, undertaking a series of actions to combat desertification, desertification prevention and control support in China<sup>[14]</sup>.

### 3.3 Science and technology support

#### 3.3.1 Scientific research and experimental demonstration

The national desertification scientific research system includes basic and applied research and the application of new technology. The government will continue to support China's desertification prevention and control in science and technology development and planning. It will also continue to strengthen the research on desertification control theory and application technology through the

National Natural Science Foundation of China, the National Key Basic Research and Development Program (program 973), the National High Technology Research and Development Program (program 863), environmental protection industry scientific research, the international science and technology cooperation platform base construction for deployment, and increased investment (with total funding of more than 300 million CNY) in support of the Gobi desert. Also it will strengthen the survey of basic information, the study of the mechanisms of desertification, and the restoration, reconstruction and application of amelioration of vegetation degradation, and research on the key technology for desertification control.

With China's Twelfth Five-Year Plan, desertification control technology includes selection of drought tolerant sand-fixing plants, in-depth studies on salt and cold resistance, and excellence in economic plant resource selection, and establishment of a rapid breeding technology system. This will involve land management and conservation of the vegetation in the desertification area, integrating a number of effective sand-stabilizing methods, and promotion of the fast recovery of vegetation and water resources through technology. At the same time, according to the main problems facing different bioclimatic desertification zones, existing mature technologies will support integrated control of different types of desertified land.

China pays attention to prevention and cure, and full consideration to the natural and social economic conditions in desert areas, and has formed a series of technical systems and successful models, including highways and railways protection technology systems, afforestation systems and sand-industry systems for farmland shelter belts.

In the application and promotion of desertification prevention and control technology, state, province (city, district) and county (city) have established a network of technology promotion. Agricultural, forestry, animal husbandry practical technology and related information can be shared in time, including a large number of desertification control and information technologies. The national agriculture, forestry, animal husbandry industry technology promotion agencies at all levels are mainly responsible for organizing and promoting the development and application of agriculture, forestry, animal husbandry product processing and comprehensive utilization technology. These organizational developments promote utilization of fine varieties, improved agricultural cultivation and field management technology, sustainable forest management and afforestation technology, pasture management technology, and vigorously conduct scientific and technical training to improve the skills of farmers and herdsmen. In addition, government departments and institutions of higher learning regularly undertake occupational training, publish technology promotion manuals, promote understanding of desertification prevention and control technology.

### 3.3.2 Desertification monitoring, early warning and technical standardization

Since the beginning of 1994, China has undertaken national desertification monitoring, macro monitoring of desertification and monitoring of special sensitive areas in conjunction with the national, regional and provincial monitoring centers. This involves locating monitoring stations and monitoring systems based on fixed sampling lines, covering the whole country of more than 30 provinces and 500 counties. The national macro monitoring exercise conducted every 5 years has issued national desertification monitoring reports five times and rocky desertification monitoring twice, thus providing data for planning and policy formulation for national desertification control regulations.

Sandstorms are affected by desertification in the main meteorological disaster area, so the country has established ground truth monitoring, remote sensing, satellite imagery and environmental monitoring system. Since 2004, China continues to increase the intensity of monitoring and warning services for sandstorms and to establish monitoring stations in seriously affected areas. It also continues to strengthen the application of meteorological satellites for real-time monitoring of the spatial distribution and intensity of sandstorms. The sandstorm monitoring program has formed a comprehensive monitoring network, set up an Asia sandstorm numerical prediction system and records the occurrence of dust storms. The process of tracking and monitoring the development and influence of sandstorms provides forecasting and warning services to the government and the public<sup>[14]</sup>.

The Desert Ecosystem Observation and Research Network is an important part of the terrestrial ecosystem research network. At present, the network covers eight deserts in China; the four sandy deserts, (including some atypical sandy land in South-west China), karst rocky desertification, and dry hot valley areas with special environments. At present, it has approved the establishment of 24 desert ecological stations, providing a set of observations and scientific demonstrations for the prevention and control of desertification and regional economic construction based on the results of the long-term observations by this network.

Standardization of desertification control technology and ecological protection measures are important. In 2008, the National Standardization Technical Committee approved the establishment of the national desertification control authority. At present, this has established *Technical specification for sand control*, *Technical code for monitoring of desertification*, *Land desertification monitoring methods*, *Sandstorm monitoring specification*, *Closing (sand) technical specification for afforestation*, *The sandy grassland pasture reseeding technical specification*, *National Standard Technical Specification for the surrounding areas of Grassland Desertification Remote*

*Sensing Monitoring, Desert ecosystem observation technical specification, Desert Ecosystem Observation and research station construction specification, Extreme arid desert ecosystem observation index system, Drought, observation the index system of desert ecosystem in semi-arid region located, Observation index of sub humid arid dune ecosystem, Technical specification for oasis protection forest system construction, Beijing and Tianjin sandstorm source control project monitoring and evaluation of the social and economic benefits index.* A series of industry standards for obtaining data on desertification and dust storms and other natural disasters and the development of technical specifications has greatly improved the precision and accuracy of China's prediction of desertification and sandstorm development trends. These standards have been widely used in the prevention of desertification and ecological engineering construction and other fields, effectively improving the quality and efficiency of construction, monitoring and scientific research.

### 3.4 Laws and statutes

In 2001, the Chinese government enacted an anti-desertification law, confirming the basic principles of the system and the conduct of prevention and control of desertification in China. The responsibility and obligation of society in the prevention and control of desertification is the legal basis that guides the work of prevention and control of desertification in China. At the same time, forest, grassland, land contract, soil and water conservation, water, and environmental laws and other relevant laws, and the prevention and control of desertification are closely related and must be compliant. After nearly 30 years of legislative practice, China has basically established a legal system for combating desertification.

Since the 2001 establishment of the anti-desertification law, 13 provinces have issued implementation measures or regulations. In 2002, the State Council passed the Returning Farmland to Forest Ordinance, to significantly guide farmland area work. In 2007, the state established the Regulations for the Development of Hydrology for conservation, protection of water resources and disaster prevention, and to provide guidance and services. In 2009, in order to prevent and reduce the losses caused by the drought disaster and ecological security, the State Council passed the Regulations of Drought Resistance. In the drought of 2010, China's Meteorological Bureau issued the National Meteorological Disaster Emergency Plan, including the prevention and response to the events of meteorological disasters such as sandstorms.

In 2005, the State Council made a decision to further accelerate the prevention and control of desertification, and to improve the relevant policies and regulations, and to develop the *who invests, who benefits, who controls* basic policy, which closely link desertification and economic development. In recent years, the state has introduced

various preferential policies and support for the prevention and control of desertification.

#### 3.4.1 Forestry subsidy policy

In 2012, the central government specified 17 provinces (autonomous regions and municipalities directly under the central government) for forest insurance premium subsidies, while the area of forest-tending subsidies in 2011 increased by 12%, afforestation subsidies pilot provinces are set to expand to the whole country. For Inner Mongolia, Ningxia, Gansu, Xinjiang, Qinghai, Shaanxi, Shanxi, and other provinces and autonomous regions seriously affected by desertification, shrubbery had subsidies increased to 3000 CNY·hm<sup>-2</sup>, 1200 CNY higher than the other provinces (State Forestry Bureau, 2013)<sup>[15]</sup>.

#### 3.4.2 Grassland ecological protection grant award

In 2011, the central government implemented grassland ecological protection grant incentives in eight provinces. In 2012, five other provinces were included, which meant that all pastoral and semi-pastoral counties in provinces and autonomous regions affected by desertification were covered by the scope of this initiative.

#### 3.4.3 Provision for the protection of desertified land

From 2013, for Inner Mongolia, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang regions, the country agreed to support the development of the conservation areas for desertified land pilot grants. The central government funded 300 million CNY of pilot grants, mainly for the conservation management and protection facilities construction areas, patrol facilities, sand dune stabilization and equipment purchase<sup>[16]</sup>.

#### 3.4.4 Preferential tax policy

Sand areas that use wood residues, small firewood, straw and willow products for comprehensive utilization of self-produced raw materials were given an 80% refund of value added tax<sup>[17]</sup>. Project income from sand-area enterprises generating agriculture, forestry, animal husbandry, and fishery may be exempt from enterprise income tax.

#### 3.4.5 Ecological compensation

In 2004, China formally established a compensation mechanism for forest ecological benefits through the central and local financial arrangements of the forest ecological benefit compensation fund. At present, the central government compensation fund is based on national forest ownership with different compensation standards. The state-owned national forest average subsidy

standard is  $12.5 \text{ CNY} \cdot \text{yr}^{-1} \cdot \text{hm}^{-2}$  and for collective and individually owned areas the subsidy is  $25 \text{ CNY} \cdot \text{yr}^{-1} \cdot \text{hm}^{-2}$ <sup>[18]</sup>. In 2016, the general office of the State Council issued an opinion document on optimal compensation mechanisms for ecological protection to 2020 and the protection of resources and ecological systems in sandy areas, and the management and protection mechanisms are based on government purchasing services<sup>[19]</sup>.

## 4 China's solution of global governance for combating desertification

### 4.1 Action to combat desertification at a global level

Desertification is a critical issue for global ecology. It cannot be controlled by one country and all affected countries need to join together to mitigate desertification through strong efforts of human communities and partnership with other stakeholders. In 2012, the UNCCD called for global action to realize a strategic vision of land degradation neutrality (LDN) by 2030. UNCCD encouraged the international community to focus not only on the prevention and control of land degradation, but also the restoration of the degraded land<sup>[10]</sup>. In September 2015, the United Nations Sustainable Development Summit adopted the 2030 Agenda for Sustainable Development and proposed 17 SDGs. Goal 15 focuses on the protection, restoration and promotion of sustainable use of terrestrial ecosystems, sustainable management of forests, combating

desertification, and halting and reversing land degradation and halting biodiversity loss. Goal 15.3 for 2030 is to combat desertification, drought and floods, and strive to achieve a land degradation-neutral world.

China, a party of the UNCCD, has planned actions to combat desertification, to fulfil its obligations under the UNCCD, and has made significant achievements and contributions to mitigate land degradation and combat desertification at a global level (Fig. 1). China is a leading country in combating desertification and mitigation of land degradation, and will continue to actively contribute to solving desertification in the world (see the chart indicating the strategy and actions in China's anti-desertification approach). China has periodically developed its National Action Plan to Combat Desertification (1995–2000, 2001–2005, 2005–2010 and 2011–2020), in line with the ten-year strategy of UNCCD and SDGs, which defined and reorientated the direction and key priority areas for combating desertification. China has created its first state law to combat desertification, with a series of regulations for prevention and control of dust and sand storms, and a comprehensive legislative system targeting desertification and land degradation. Every 5 years China conducts nationwide systematic desertification monitoring to measure trends in desertification, and to provide accurate data and scientific evidence for conducting quantitative evaluation of the achievements in combating desertification. At the end of 2015, China published the Fifth Desertification Monitoring Bulletin, which indicated that the area of desertification and land degradation in China is reducing

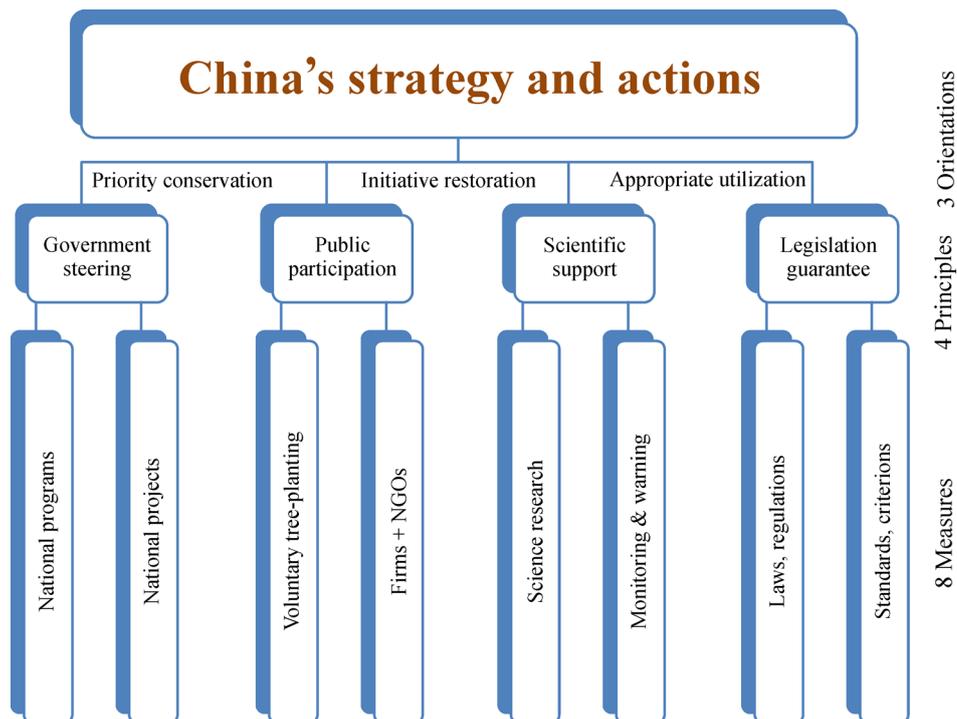


Fig. 1 China's strategy and actions to combat desertification

and the severity of desertification is decreasing. In comparison with the findings of the Fourth Desertification Monitoring Bulletin, it is estimated that areas of desertification and land degradation have been reduced by 120100 km<sup>2</sup>. The rate of the most severe desertification has reduced by 5%<sup>[20]</sup>. China has achieved this remarkable LDN target and actively leads global action to combat desertification and mitigate land degradation. Chinese expertise can be extended to and implemented in other affected countries, and global monitoring and evaluation can be conducted periodically to evaluate the realization of the LDN target.

#### 4.2 Promotion of the regional cooperation to combat desertification and mitigate land degradation

In March 2015, the Chinese government launched the Vision and Actions on Promotion for Jointly Building the Silk Road Economic Belt and Twenty-first Century Maritime Silk Road, which emphasized the necessity and importance of cooperation on eco-environment, biodiversity and climate adaptation among the countries along the Belt and Road to jointly make a Green Silk Road. Sixty five countries are involved in the Belt and Road Initiative and the total land area is about 55 million km<sup>2</sup>, accounting for about 41% of the total area in the world and involving a population of 4.4 billion. Most of these countries are parties of the UNCCD and are suffering from different types and degrees of land degradation and desertification. Declaring the opportunity to mutually build the Green Silk Road, the State Forestry Administration of China, in collaboration with UNCCD, launched The Belt and Road Joint Action Initiative for Combating Desertification on 17 June 2016. The Joint Action Initiative called on countries along the Belt and Road to work together to combat desertification and to reverse land degradation with joint efforts and mutual support. In September 2017, the thirteenth session of the Conference of the Parties of UNCCD will be held in China. The Chinese government is leading by building The Belt and Road Combating Desertification Cooperative Mechanism to operate and realize the Belt and Road Joint Action Initiative for Combating Desertification by promoting conferences, information sharing, joint project cooperation, finance resource mobilization and compilation of a Desert Nature Heritage List.

China has actively participated in the First Meeting of Ministers Responsible for Forestry in Greater Central Asia (China, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan and Uzbekistan), the North-east Asia Network for Combating Desertification (DLDD-NEAN) (China, Japan, Republic of Korea and Mongolia) and other regional cooperative mechanism to strengthen the regional and subregional cooperation to combat desertification and mitigate land degradation. The Greater Central Asia Ministerial Conference Mechanism is at the moment

the only dialog and communication platform for forestry ministers in the region. Its aim is to promote forestry development, to conduct substantial cooperation and accelerate and coordinate regional forestry development through ministerial dialog. In May 2016, the first Greater Central Asia Forestry Ministerial Conference was held in the capital of Kazakhstan and endorsed The Astana Declaration and the topic of combating desertification was prioritized as the key cooperative project of the region. In July 2015, a DLDD-NEAN Workshop on Combating Desertification and Mitigation Land Degradation was held in Beijing and the Joint Action Plan to combat Desertification for the North-east Asian subregion was adopted. It focused on (1) establishment of a platform for information exchange and expertise sharing, (2) creation of cooperative linkages among governmental departments and civil society organizations, public-private partnership, and close combination of research and development with grass-roots practice, (3) supporting regional ecology restoration and sustainable utilization of resources, and (4) contributions to achieve LDN targets in the North-east Asia subregion<sup>[21]</sup>.

#### 4.3 Accelerating bilateral cooperation to combat desertification

China has deepened its bilateral cooperation with Arab and African states in mitigating land degradation and combating desertification via the China-Arab Cooperative Forum and the China-Africa Cooperative Forum. Cooperation in combating desertification is one of the main cooperative priority areas between China and the Arab states. From 2014, combating desertification is included in the China-Arab States Cooperative Forum 2016-2018 Action Implementation Plan. This Plan strengthens the Mutual Cooperation Framework for Combating Desertification, operation of the MoU between the Arab Centre for Arid Land Studies and the State/Forestry Administration of China. China established the China-Arab Centre for Combating Desertification in Morocco and launched and organized an academic and technical workshop on combating desertification and drought preparedness. Both China and African countries face serious desertification which is one of the most severe eco-environmental issues and desertification mitigation is a common interest for China and African countries. In June 2006, the China-Africa Cooperation Forum Summit was held in Beijing and combating desertification was brought into the Beijing Action Plan of the China-Africa Cooperation Forum. The Ministry of Commerce and State Forestry Administration organize periodically organizes joint workshops/seminars on combating desertification and trains African participants/students in China as a concrete approach to operationalize the Beijing Action Plan of the China-Africa Cooperation Forum. All participants and trainees learn Chinese expertise, technologies and know-how, and

policies on combating desertification through classroom presentations, discussions, study tours and field observations. In April 2017, China and Egypt signed the MoU between the State Forestry Administration of China and Ministry of Agriculture of Egypt. Both parties agreed to promote mutual cooperation in combating desertification, particularly in the technical cooperation in demonstration projects and accelerating the popularization and application of the technologies to combat desertification and reverse land degradation and build a China-Africa Demonstration and Training Centre For Combating Desertification.

#### 4.4 UNCCD future implementation and global actions

First, it is necessary to develop a UNCCD agreement to unify the Global Weights and Measures to Implement the Convention and set an implementation date. UNCCD does not have any protocols or agreements which both UNFCCC and CBD have endorsed during their early years. Although UNCCD has established its LDN targets and some indicators to measure land productivity, land cover and soil organic carbon, there is lack of unified evaluation methodologies and benchmarks. It is suggested that a UNCCD Conference of the Parties should consider and develop a protocol similar to the Kyoto Protocol and Paris Agreement of the UNFCCC to create measurable, comparable and examinable rigid indicators to implement the UNCCD, to develop LDN evaluation methodology and technology, to provide unified global scientific evaluation methodology and indicators, to assess fairly the achievements and efforts to combat desertification and restore land degradation at national level and to strengthen the global joint action to implement the UNCCD.

Second, a global observation network should be established to conduct desertification monitoring and evaluation based on multiple sources of remote sensing data and carry out a periodic global desertification monitoring and evaluation (once every 5 years) for the purpose of understanding the land change by using satellite imagery. The compilation of desertification combating technologies categories and technical requirement categories, the sustainable land management of desertification-prone lands, an inventory of ecology restoration technology, information sharing and exchange platform. The establishment of an information platform of sand-fixing plants, drought-resistance and salt-tolerant varieties, the promotion of information exchange, the evaluation and value-cost calculation of global desert ecosystem services are all essential and are the main contents of the Global Observation Network.

Third, it is suggested to compile a global natural desert heritage inventory and this is aimed at preserving original sandy desert landscapes for future generations. China, in collaboration with UNCCD, IUCN, UNESCO and the World Desert Foundation, will jointly compile an

inventory of the main sandy deserts of the world, set up national desert parks, arid land nature reserves and closed protection areas to effectively protect desert nature and cultural heritage.

Fourth, China will launch a global action to combat desertification and build human communities to combat desertification based on the advanced pilot and case studies on LDN in China and work together to meet the LDN target for 2030. UNCCD, UNEP, FAO and UNESCO will be encouraged to have coordinative roles to effectively strengthen the China-Arab Cooperation Forum and the China-Africa Cooperation Forum, to promote multilateral cooperation among the Belt and Road related regions, Greater Central Asia and North-east Asia, to implement the Belt and Road Joint Action Plan for Combating Desertification, and support and accelerate the smooth cooperation to combat desertification and mitigate land degradation at subregional, regional and global levels<sup>[22]</sup>.

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## References

1. Le Houérou H N. Man-made deserts: desertization processes and threats. *Arid Land Research and Management*, 2002, **16**(1): 1–36
2. Le Houérou H N. The nature and causes of desertization, *Arid Land Newsletter*, 1976, (3): 1–7
3. Mortimore M. Adapting to drought: farmers, famines, and desertification in west Africa. Cambridge: *Cambridge University Press*, 1989
4. Behnke R H, Mortimore M. The end of desertification? Disputing environmental change in the drylands. Berlin Heidelberg: *Springer-Verlag*, 2016
5. Lu Q, Yang Y L. Global sandstorm warning. Beijing: *China Environmental Science Press*, 2001 (in Chinese)
6. Lu Q, Yang Y L, Wang S, Liu T. Revelation of China's sandy control. Beijing: *Science Press*, 2004 (in Chinese)
7. Lu Q. Desertification: urgent challenge China faces. Beijing: *Kaiming Press*, 2000, 12–20 (in Chinese)
8. Wang G C, Wang X Q, Wu B, Lu Q. China's desertification and its

- prevention and control. Beijing: *Higher Education Press*, 2005 (in Chinese)
9. Zhu J F, Zhu Z D. The prevention and control of sandy desertification in China. Beijing: *China Forestry Press*, 2002 (in Chinese)
  10. UNCCD. Zero net land degradation, a sustainable development goal for Rio + 20. *UNCCD Secretariat Policy Brief*, 2012
  11. The State Council. Implementation of the universal compulsory tree planting campaign, 1982 (in Chinese)
  12. The Ministers of China participate in tree planting activities. *Guangmin Daily*, 2017–3–26 (in Chinese)
  13. National Development and Reform Commission and other 12 ministries. National ecological protection and rehabilitation plan (2013–2020), 2014 (in Chinese)
  14. China National Committee for the Implementation of the UNCCD. China national report on the implementation of the United Nation's convention to combat desertification. 2014
  15. State Forestry Administration. China forestry development report 2012. Beijing: *China Forestry Press*, 2013 (in Chinese)
  16. State Forestry Administration. China forestry development report 2013. Beijing: *China Forestry Press*, 2014 (in Chinese)
  17. Ministry of Finance, State Administration of Taxation. Notice on the policy of value-added-tax on comprehensive utilization of agricultural and forestry residues as raw material, 2009 (in Chinese)
  18. State Forestry Administration, Ministry of Finance. Administrative measures for compensation fund for forest ecological benefit of central government, 2009 (in Chinese)
  19. General Office of the State Council. Opinions on improve the ecological protection and compensation mechanism, 2016 (in Chinese)
  20. State Forestry Administration. The 5th national monitoring survey of desertification and sandification, 2015 (in Chinese)
  21. State Forestry Administration. China forestry yearbook 2015. Beijing: *China Forestry Press*, 2015
  22. Sustainable Developmentknowledge Platform. Desertification, land degradation and drought, 2015