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Tao Wang · Atsushi Tsunekawa
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Combating Aeolian Desertification in Northeast Asia

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Preface

Desertification, defined by the United Nations Convention to Combat Desertification (UNCCD) in 1994, means "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities." Desertification is primarily caused by soil erosion that occurs due to wind and/or water erosion; deterioration of the physical, chemical, and biological or economic properties of soil; and long-term loss of natural vegetation. Globally, approximately 24% of the land is experiencing desertification, and 110 countries are at risk of desertification. The livelihood of 1.5 billion people relies on desertified land. The desertification-induced annual loss of arable land is 8000 km^2, and the annual economic cost is 42 billion USD (UNCCD 2009).

Aeolian desertification is a type of desertification caused by wind erosion through aeolian processes. This type of desertification is often accompanied by processes related to the occurrence of blown sand (deflation, ground surface coarsening, sand dune formation, etc.) in formerly nondesertified areas that serve as a baseline area (benchmark). We defined aeolian desertification as land degradation caused by wind erosion mainly resulting from human impacts in arid, semi-arid, and dry sub-humid regions of northern China and southern Mongolia.

Since 1980, Professor Seiei Toyama from Tottori University, Japan, has been devoted to research and efforts related to combating aeolian desertification and studying sandy land with his team and collaborating researchers from the Lanzhou Institute of Desert Research, the Chinese Academy of Sciences, and different stakeholders in Inner Mongolia, Ningxia, and Gansu provinces. In the past four decades, many universities and national research institutes in China and Japan have systematically and holistically collaborated to focus on aeolian desertification processes and control techniques. The collaborative activities have included large spatial field surveys, in situ field observations, laboratory analyses, theoretical compilations, development of control techniques, and student exchanges, and these activities have had good results. In 2004, a trilateral framework was developed for China-Japan-Mongolia scientists to work on aeolian desertification issues. The three sides reached an agreement in terms of academic exchanges; field surveys; data sharing; student, environmental manager, and practitioner exchanges; and field station establishment and improvement.

Based on the achievements of these collaborative efforts that were implemented to understand aeolian desertification processes and the techniques to combat, we compiled a book, *Combating Aeolian Desertification in Northeast Asia*, with the following conclusions and outcomes:

1. According to the actual situations, research, and practices in Northeast Asia, we provided a definition of aeolian desertification and its implications, which allowed us to clearly understand the research object and issues, spatiotemporal scope, and targets for combating aeolian desertification.
2. To understand the impacts of natural climatic variations and human activities on aeolian desertification, we provided results on the analysis of the variations in the natural environment, human activities, and temporal dynamics of aeolian desertification derived from a remote-sensing dataset.
3. In view of the comprehensive study on the process of aeolian desertification by both natural factors with wind erosion and human land use patterns and intensities, we concluded that human activities caused more than 80% of the aeolian desertification in Northern China over the last 60 years. Thus, improper land use is the primary driver of aeolian desertification, and only appropriate human activities will successfully combat aeolian desertification.
4. We argued that environmental policies and national ecological engineering projects are important for combating aeolian desertification; we demonstrated the efficacy of physical, biological, and comprehensive protection systems in terms of combating aeolian desertification, and we provided information on how to alleviate poverty and gain ecological benefits.
5. We identified successful practices for combating aeolian desertification in China and Mongolia that can serve as references to other countries that face the same aeolian desertification problems.
6. This work showed that sustainable land management is necessary to improve aeolian desertification control efforts.

The collaboration among Japan, China, and Mongolia was financially supported by the Japan Society for the Promotion of Science, Japan Science and Technology Agency, Japan International Cooperation Agency, Ministry of Science and Technology of China, Chinese Academy of Forestry, Chinese Academy of Science, National Science Foundation of China, and Mongolian Academy of Science. This support indicates the level of concern related to combating aeolian desertification among these three nations, and the collaboration among the three nations also showed that aeolian desertification is not only an environmental-social-ecological problem of an individual country but also a transboundary concern. Efforts and collaborations among Japan, China, and Mongolia are indispensable to addressing aeolian desertification.

We thank all the authors for submitting their valuable manuscripts to this book and all the scientists, staff, and students who participated in and contributed to the

research introduced in this book. We are grateful to Springer Japan and its staff for their assistance and encouragement.

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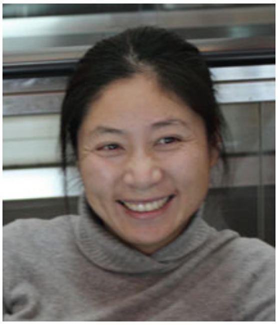
About the Editors

Tao Wang is a professor at Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences (CSA). He obtained his doctoral degree from Lanzhou Institute of Desert Research, CAS. He has been at the forefront of aeolian desertification and disaster research and control since 1983, and obtained encouraging results on the status, causes, blown sand physics and biology process, development, and reversal trend of aeolian desertification in Northern China. His work has helped the national policy maker and organ of authority to take notice of aeolian desertification and provided theoretical foundation and technique system for implementation of national layout and projects to combat aeolian desertification and disaster. He served the UNCCD for years as member of the Scientific Advisory Committee of Third Scientific Conference (SAC, UNCCD) and as member of Science-Policy Interface (SPI) of the UNCCD.

Atsushi Tsunekawa is a professor at Arid Land Research Center, Tottori University (Japan). He graduated from the Graduate School of Agricultural Sciences, University of Tokyo, after which he joined the National Institute for Environmental Studies, Japan. Currently, he serves as a professor at the Arid Land Research Center, Tottori University, and also serves as a head of Strategic Management Office of International Platform for Dryland Research and Education, Tottori University. His primary scholarly interests are developing sustainable land management (SLM) technologies and approaches to restore degraded land and improve farmers' livelihood, and monitoring and modeling of terrestrial ecosystems under climate change using remote sensing and GIS. He has been selected as a Science and Technology Correspondent from Japan to the Committee on Science and Technology of United Nations Convention to Combat Desertification.



Xian Xue is a professor at Northwest Institute of Eco-Environment and Resources (NIEER), Chinese Academy of Sciences. She obtained her PhD in physical geography from the Graduate School at the Chinese Academy of Sciences in 2002. She currently leads the Department of Desert and Desertification in the NIEER, the Dryland Salinization Station of NIEER, and the Salinization Research Station of Gansu Province. Her main research fields are desertification and restoration, and climate and environmental change in arid and cold regions. Her interest focuses on the dynamic process and mechanism of desertification and its rehabilitation. One of her current research is exploring the impact of global warming and human activity on land degradation in the arid and alpine ecosystems. Her other work is to explore restoration possibilities of degraded land in the drylands by integrating water management, sustainable agriculture, and biological techniques with her team.

Yasunori Kurosaki is a professor at Arid Land Research Center (ALRC), Tottori University, Japan. He obtained his PhD from Graduate School of Life and Environmental Sciences, University of Tsukuba. His main research theme is elucidation of the aeolian dust emission mechanisms. Prof. Kurosaki began his research at the Meteorological Research Institute, Japan Meteorological Agency, in 2001, and he has continued it at Chiba University, Georgia Institute of Technology, and Tottori University. He has elucidated the causes of aeolian dust emission that change with time and place in drylands of Northeastern Asia mainly by analyzing meteorological observatory data and GIS data such as satellite data. He has also studied it by field surveys in the Gobi Desert. His interest and the purpose of his research are to apply his elucidated mechanisms to improve numerical aeolian dust models and to prevent wind erosion and aeolian dust damage.

Part I
Overview of Aeolian Desertification

Chapter 1
Definition of Aeolian Desertification and Its Implications

Tao Wang

Abstract In this book, land degradation is defined as a negative trend in land conditions resulting from various factors, including climatic variations and human activities, and expressed as a long-term reduction or loss in biological productivity, ecological integrity, or value to humans. Land degradation is caused by the processes related to soil degradation (including soil erosion, salinization, and soil fertility loss) and ecosystem degradation (including reduction in vegetation cover, reduction in biomass, and decrease in biodiversity). Desertification is defined as a type of land degradation in arid, semiarid, and dry subhumid areas. Aeolian desertification is a type of desertification caused by wind erosion through aeolian processes. This type of desertification is often accompanied by processes related to the occurrence of blown sand (deflation, ground surface coarsening, sand dune formation, etc.) in formerly nondesertified areas that serve as a baseline area (benchmark), and aeolian desertification results from various factors, including overuse of land and imbalances in the fragile ecosystem under dry and windy climate conditions and loose sand surfaces. Topics related to aeolian desertification research mainly include its occurrence and developmental processes; its distribution, status, causes, and damage; its types and indicator systems; restoration options; remote sensing monitoring; and mapping.

Keywords Land degradation · Desertification · Aeolian desertification · Classification · Index system

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1.1 Concept of Aeolian Desertification and Its Development

1.1.1 Formulation of the Term "Desertification"

Aeolian desertification is one of the main types of desertification, and it is necessary to introduce the concept of desertification before explaining the definition and implications of aeolian desertification.

The term "desertification" was first presented by Aubreville, A, a French botanist, in his studies as long ago as 1949 (Aubreville 1949). In his study on the ecological problems in tropical African forest regions, he defined "desertification" as a process of environmental degradation from a forest to a grassland and then to a desert-like landscape after the destruction of forest vegetation in the region. Other researchers have been discussing the "desertification" phenomenon since the late 1950s (Zhu 1959; Le Houerou 1962; Hou 1973). However, this topic did not attract the attention of the international community until 1968–1973, when the serious and extended drought in West Africa intensified the process of land desertification in the Sahel region at the southern margin of the Sahara Desert. Desertification has received widespread attention all over the world, as confirmed by the creation of the United Nations Conference on Desertification in Nairobi in 1977 (UN Secretariat of the Conference on Desertification 1977). It was described in the UN Conference on Desertification (UNCD 1978) as: "Desertification is the diminution or destruction of the biological potential of the land, which can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems, and has diminished or destroyed the biological potential…The deterioration of productive ecosystems is an obvious and serious threat to human progress. In general, the quest for ever-greater productivity has intensified exploitation and has carried disturbance by man into less productive and more fragile lands. Overexploitation gives rise to degradation of vegetation, soil and water, the three elements which serve as the natural foundation for human existence. In exceptionally fragile ecosystems, such as those on the desert margins, the loss of biological productivity through the degradation of plant, animal, soil and water resources can easily become irreversible, and permanently reduce their capacity to support human life. Desertification is a self-accelerating process, and as it advances, rehabilitation costs rise exponentially. Action to combat desertification is required urgently before the costs of rehabilitation rise beyond practical possibility or before the opportunity to act is lost forever."

After summarizing the situation and development trends of land desertification since 1977, the United Nations Conference on Environment and Development (UNCED, held in Rio de Janeiro, Brazil in 1992) complementarily defined desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (UNCED 1992). In the definition, the arid, semiarid, and dry subhumid areas are classified by aridityindex (AI) (UNEP 1992; Table 1.1).

Table 1.1 Climate zones classified by the aridity index

Climate zone	arid index (AI)
Arid	0.05<AI<0.20
Semiarid	0.20<AI<0.50
Dry subhumid	0.50<AI<0.65
Humid	>0.65

Note: AI = *P*/APE, where *P* is annual precipitation (mm) and APE is the revised potential evapotranspiration (mm)

Although a number of research articles, papers, and reports from many countries have shown growing interest in the desertification issue (Glantz 1977; Quintanilla 1981; Zhu and Liu 1981; Zonn 1981; Wang 1989, 1991, 1993; Wang and Wang 1989; Zhu and Wang 1990, 1992a, b, 1993), drought was neither the first indicator of desertification nor the only reason for scientific interest in it. Desertification is acknowledged to be a complex phenomenon requiring the expertise of researchers in disciplines such as climatology, meteorology, soil science, hydrology, range science, agronomy, geography, political science, economics, and anthropology. To date, the term "desertification" is still widely interpreted globally in many different ways by researchers in these and other disciplines, and it has also been defined from many national and institutional perspectives, each emphasizing different aspects of the phenomenon. Some reviews of desertification literature show great diversity (and confusion) among definitions (Carder 1981; Chen 1994). Hence, the United Nations Convention to Combat Desertification (UNCCD, signed at the Diplomatic Conference in Paris, France, in 1994) further clarified the three basic elements of the above definition of desertification: (a) desertification is the result of a combination of factors such as climate change (natural factors) and human activities; (b) desertification occurs mainly in arid, semiarid, and dry subhumid areas with fragile ecological environments; and (c) desertification is part of the global land degradation process (UNCCD 2000). The UNCCD also highlighted that it is important to note that desertification is not the natural process of deserts expanding into new regions; it is a form of land degradation caused primarily by human activity in vulnerable areas. All regions in which the ratio of the total annual precipitation to potential evapotranspiration (P/PET) ranges from 0.05 to 0.65 should be considered vulnerable to desertification, and such regions constitute approximately 40% of the global terrestrial area. Broadly, land degradation refers to the processes of soil degradation (including soil erosion, salinization, and soil fertility loss) and ecosystem degradation (including reduction of vegetation cover, reduction in biomass, and decrease of biodiversity), but desertification is only part of the process.

1.1.2 The Term "Aeolian Desertification" and Its Development

As mentioned above, the term "desertification" originated officially from the southern Saharan region of Africa, and as the UN Conference on Desertification described, its salient feature is that "desertification can lead ultimately to desert-like conditions." With the deterioration of the global ecological environment and the expansion of the countries involved in the discussion, the scope of the discussion has been extended from arid areas to dry subhumid areas, and the causes of land degradation discussed are not limited to wind erosion but have involved water erosion, secondary salinization, and other factors. Desertification no longer has its original narrow concept; it now involves problems that are constantly growing, and its meaning is constantly expanding. Therefore, the use of the term under different national backgrounds requires a clear conceptual scope (Zhu 1994, 1999; Zhu and Chen 1994; Ci 1995; Chen 2001, 2002).

China is suffering from serious desertification. As early as the late 1950s, Professor Zhu noted that owing to anthropogenic causes, some former nondesert land had changed into desert and approximately 530,000 ha of sandy grasslands in Shaanxi and Inner Mongolia were "man-made desert" (Zhu 1959). He also stressed that water is a weapon to conquer deserts, and we can use water to open oases in deserts. Thus, researchers in China conducted studies on aeolian sand movement, water balance, physiological and ecological characteristics of sand binders, and vegetal sand stabilization measures. In these studies, special attention was given to the environmental degradation and the spread of deserts caused by anthropogenic factors. After the UN Conference on Desertification in 1977, the priority in desert research in China gradually shifted to the study of desertification processes and their control, and the studied regions gradually shifted from arid and hyperarid zones to the semiarid and part of subhumid regions that had relatively better eco-environmental conditions and higher productivity but were facing desertification problems. According to the situation in China, desertification in China mainly includes desertification from wind erosion, water erosion, soil salinization, and freeze-thaw. In northern China, desertification mainly occurs from wind erosion, which is now referred to as "aeolian desertification" or "sandy desertification." Although there has been international consensus on the concept of desertification since the UNCCD, the concepts of "desertification" and "aeolian desertification" have been used in contrasting ways for a relatively a long time in China, resulting in very different research results, especially in terms of desertification areas or aeolian desertification areas (Li 1994; Wang 1994; Zhu 1994, 1999; Zhu and Chen 1994; Ci 1995; Zhu and Zhu 1999; Chen 2001, 2002; Yi 2005).

In this book, we combined the research by Zhu and Chen (Zhu and Chen 1994) and the UNCCD in 1994 and CCICCD (1994) and defined aeolian desertification as land degradation in arid, semiarid, and dry subhumid regions with the occurrence of blown sand processes (deflation, ground surface coarsening, sand dune formation, etc.) in formerly nondesert areas as the main indicator, and the occurrence of this type of desertification has resulted from various factors, including overuse of land and an imbalance in the fragile ecosystem under the dry and windy climate conditions and loose sand surface.

1.2 Scope of Research on Aeolian Desertification

After the UN Conference on Desertification in 1977, scientific research on deserts in China changed from being sandy desert-oriented to aeolian desertification-oriented. Since that time, the process of aeolian desertification and its control mechanisms have become important components of desert scientific research. At the same time, some important information on aeolian desertification that is different from that on sandy desertification has been clarified (Zhu and Liu 1981; Zhu and Wang 1992a; Wang et al. 1999):

1. Aeolian desertification in China mainly occurred in the human historical period, especially over the last 100 years; aeolian desertification is mainly distributed where the earth's surface is covered by loose sand materials and winds are frequent in arid, semiarid, and even part of subhumid zones. This desertification type occurs in limited areas and mostly in patches on farmlands and grasslands, with simple and small aeolian sand features. Sandy desert is a barren area where the ground is completely covered with sand dunes, plants are very rare, rain is scarce, and the air is dry; sandy deserts are generally aeolian landforms such as the Taklimakan Desert and the Badain Jaran Desert. Sandy deserts in China were mainly formed during different stages of the Quaternary period; they are the outcomes of the dry climate and abundant surface sand source, and they mainly occur in arid zones, with large areas and complex aeolian landforms.
2. Aeolian desertification develops or reverses in a short period under the same climatic conditions due to the negative or positive effects of human economic activities. Recent climatic conditions and their variation amplitudes are insufficient to cause a large expansion or shrinkage of sandy deserts. In the past several decades, aeolian desertification developed rapidly due to the influences of undue human economic activities (overcultivating, overgrazing, overcutting, and overusing water resources) rather than due to climate change. Sandy deserts were formed under the influences of various natural factors, while the occurrence of aeolian desertification is mainly due to anthropogenic factors in addition to natural factors. Sandy deserts varied with the changes in the Quaternary climate; in the dry-cold stage, they expanded and became mobile, but in the warm-wet stage, they shrank and became fixed.
3. Aeolian desertification is a gradual process, and wind acts as the power to shape the landscape of desertified land surfaces. Therefore, blowing sand, wind erosion, and the morphological characteristics of wind-deposited surfaces can be used as quantitative indicators of the degree of aeolian desertification development. Aeolian desertification intensity and its spatial extent are related to the degree

of drought and human and animal pressure on land. With the interaction of these factors and the action of wind force, aeolian desertification can spontaneously spread; it leads to sand dune encroachment, land biological productivity reduction, and available land resource loss, but it can also be reversed or self-restored, depending upon natural conditions (especially water conditions), landscape complexity, and human activity intensity.

In summary, studies on sandy deserts and aeolian desertification do not belong to the same category in terms of time, space, cause, developmental trend, restoration, and utilization. Research on aeolian desertification mainly includes the following aspects:

- Occurrence and development processes of aeolian desertification and their types in arid, semiarid, and dry subhumid zones in northern China, especially in regions with fragile eco-environments and frequent human activities
- Studies on aeolian desertification status, distribution, causes, damage, and indicator systems
- Establishment of restoration experiments and demonstration projects for different desertified land types, i.e., examples at the margin of an oasis, in the desert steppe zone, in the semiarid agropastoral ecotone, and in some other typical areas
- Remote sensing monitoring, field investigations, and aeolian desertification mapping

1.3 Index System of Aeolian Desertification Monitoring

Aeolian desertification is a complex process of land degradation. During the process, the physical and chemical properties of soils change with the variation in the landscapes caused by sand movement. Therefore, establishing a set of identifying indicators to monitor the developmental stages of aeolian desertification is important. Although a set of indicator systems of aeolian desertification has been established by the FAO and UNEP (FAO and UNEP 1984), a practical indicator system for regional aeolian desertification monitoring and classification is still needed because of large differences from place to place. It is generally accepted that aeolian desertification indicators related to natural, human, and socioeconomic factors should be identified. However, there is currently no recognized index system of aeolian desertification in the world due to a lack of consistency in the selection of indicators. There are several commonly used classification index systems in China:

1. An aeolian desertification index system based on symbols of the aeolian desertification developmental phase (Table 1.2)
2. An aeolian desertification index system based on ecology (Table 1.3)
3. An aeolian desertification index system based on landscape configuration changes (Table 1.4)

Table 1.2 Degree of aeolian desertification based on developmental symbols (Wang 2011)

Degree	Percentage of aeolian desertification land	Features of shapes
Aeolian desertification-prone	≤5	Patches of shifting sand sparsely scatter in farmland and around water wells and residential areas
Ongoing aeolian desertification	6–25	Patches of shifting sand or blown land, farmlands suffer wind erosion
Intensively developed aeolian desertification	26–50	Sheets of shifting sand dunes and blown shrub sand dunes, interlaced with fixed and semifixed sand dunes
Severe aeolian desertification	>51	Predominant shifting sand dunes distribute densely

Table 1.3 Degree of aeolian desertification based on ecological indicators (revised according to Wang 2011)

Degree	Vegetation cover (%)	Land productivity (%)	Ratio of output to input (%)	Biomass (t/ha·a)
Latent	>60 of original	>80 of original	>80 of original	3.0–4.5
Ongoing	59–30 of original	79–50 of original	79–60 of original	2.9–1.5
Intensively developing	29–10 of original	49–20 of original	59–30 of original	1.4–1.0
Severe	9–0 of original	19–0 of original	29–0 of original	0.9–0.0

4. An aeolian desertification index system based on different land types (Table 1.5)
5. An aeolian desertification index system based on dynamic status (Table 1.6)

The results from the different evaluation systems applied to the same region were not completely consistent, which can cause confusion to in terms of the theory that guides practice. To establish a universal index system of aeolian desertification monitoring, the indicators selected should be representative and applicable and a statistical quantum, represent environmental phenomena related to aeolian desertification processes, or represent an existing specific environmental condition (Wang et al. 1998). The indicators should (a) contain clear information that is easy to obtain from observations; (b) be sensitive to variations in aeolian desertification status; (c) be suitable for repeated use; and (d) be reviewed with a quantitative check. According to the characteristics of aeolian desertification in northern China, we have established a relatively universal indicator and classification system of aeolian desertification (Table 1.7), which considers surface feature variations the main factors and considers the changes in soil, vegetation, and ecosystems the supplemental factors. We supplement several indicators to evaluate the aeolian desertification degree with the development of aeolian desertification.

Table 1.4 Degree of aeolian desertification based on landscape configuration changes (Wang 2011)

Degree	Synthetic landscape symbols
Slight aeolian desertification	1. Blowouts appear on windward slopes, with shifting sand depositing on leeward slope; rate of vegetation cover is 30–60% of nonaeolian desertified land; areas with patches of shifting sand occupy 5–25% 2. Different scales of shrub sand mounds appear; shrubs grow abundantly and thickly 3. A thin layer of sand deposits on the Earth's surface, even with gravel outcrops 4. In spring, farmland is eroded by wind, with less than a 50% loss in humus, and output is 50–80% of original yields 5. Blowouts appear where fine soil is thick, with certain vegetation cover
Moderate aeolian desertification	1. The difference between a blown slope and slip slope is obvious; vegetation cover is 10–30% of nonaeolian desertified land; area of shifting sand accounts for 25–50% 2. The whole sand mound cannot be completely covered by shrubs, with shifting sands on the windward slope 3. Small patches of shifting sand appear in the loess area, with much coarser sand and gravel at the surface but still with sparse plant cover; vegetation cover is 10–30% of the nonaeolian desertified land 4. Productivity is decreased due to wind erosion, with more than a 50% loss in humus and less than 50% of original output 5. Blowouts are mostly bare; small steep ridges emerge at the ground surface
Severe aeolian desertification	1. The whole sandy desertified area is shifting sandy land-like, with more than 50% of shifting sand and sparse vegetation, and vegetation cover is less than 10% of the nonaeolian desertified land 2. Gravel desertified area appears gobi-like, vegetation cover is below 10% of the nonaeolian desertified land, and farmlands with gravel desertification occurrence are deserted 3. Humus layer is almost blown away completely, calcic horizon or soil parent material is outcropped, and most farmlands are deserted 4. Soil residues from wind erosion appear on the Earth's surface

In remote sensing monitoring, the percentage of eroded land or shifting sand areas and its changes in a certain period are considered the key indicator (it is the easiest factor to judge and use), and the other factors are considered supplementary indicators. This is because the change in eroded land or shifting sand area is a combined result of vegetation cover, biological production, soil properties, water content, etc. Our classification system mainly relies on direct information on ground vegetation cover, plant species, and microtopographic features (Fig. 1.1). Based on this indicator system of aeolian desertification monitoring, the four types of aeolian desertification in northern China have the following features:

1. Slight aeolian desertification: (a) the blowouts appear on the windward slopes of sand dunes, there are some accumulative shifting sands on leeward slopes, vegetation cover is 30–50% of the original cover, and patches of shifting sands

Table 1.5 Degree of aeolian desertification based on different land use types (Wang 2011)

Degree	A Reactivation of fixed sand dunes	B Aeolian desertification of shrubs	C Gravel aeolian desertification	D Badland aeolian desertification	E Aeolian desertification of farmland
1 Original status (aeolian desertification-prone)	1a Fixed sand dunes or oases, farmlands	1b Dry steppe or desert steppe, steppification desert	1c Desert steppe or steppification desert	1d Dry steppe or desert steppe, steppification desert	1e Dry farmlands
2 Slight aeolian desertification	2a Blowouts appear on the windward slope; patchy shifting sand occupies 5–25%, with more than 90% of original vegetation cover	2b Shrubs flourish; shifting sand deposits under shrubs	2c Gravel is becoming concentrated at the ground surface	2d Shallow blown pits merge on the ground surface but without steep ridges	2e There is deposited sand on farmlands in spring, with obvious traces of wind erosion
3 Moderate aeolian desertification	3a The difference between blown slope and slip slope is obvious; area of shifting sand accounts for 25–50% of the original vegetation cover	3b The whole sand mound cannot be completely covered by shrubs, with shifting sand's occurrence on the windward slope	3c Substantially coarse sand and gravel at the surface but still with sparse plant cover, and vegetation cover is more than 25% of the original vegetation cover. The landscape is gravel steppe	3d Most blowouts are bare; obvious small steep ridges emerge on the Earth's surface	3e Small patches of shifting sand appear on loessial farmlands; productivity is decreased due to wind erosion, with more than a 50% loss in humus
4 Severe aeolian desertification	4a Sandy land is semishifting; area of shifting sand exceeds 50%, with less than 50%	4b Large patches of shrubs are dead; vegetation cover is below 25% of the original vegetation cover, and	4c The Earth's surface is covered by gravel completely, with minimal sand in small holes among the gravel, and vegetation	4d Soil residues from wind erosion appear on the Earth's surface, with sparse vegetation at the interdune areas, and	4e Humus layer is almost blown away completely, calcic horizon or soil parent material is outcropped, and most

(continued)

Table 1.5 (continued)

Degree	A Reactivation of fixed sand dunes	B Aeolian desertification of shrubs	C Gravel aeolian desertification	D Badland aeolian desertification	E Aeolian desertification of farmland
	of the original vegetation cover	the area of shifting sand exceeds 50%	cover is 10–25% of the original vegetation cover	farmlands with gravel desertification are deserted	sandy desertified farm-lands are deserted
5 Very severe aeolian desert-ification land	5a Shifting sand dunes or sandy land, with the veg-etation cover being less than 10% of the original vegetation cover	5b Undulated shifting sandy land, with the vegetation cover being less than 10% of the original vegetation cover	5c Gobi; vegetation cover is less than 10% of original vegetation cover	5d Yardang landscape	5e Flat sandy land or gravel land; vegetation cover is less than 10% of the original vegetation cover

Table 1.6 Degree of aeolian desertification based on dynamic status (Wang 2011)

Degree	Rate of annual increase in aeolian desertification land (%)
Reversed aeolian desertification	Negative
Stable aeolian desertification	<0.25
Developing aeolian desertification	>0.25
Thereinto: Commonly developing	0.25–3.0
Intensively developing	>3.0

Table 1.7 Index system of aeolian desertification classification (Wang 2011)

Degree	Main indicators				
	Blown-sand area (%)	Annual expansion area (%)	Vegetation cover[a](%)	Annual reduction in biomass (%)	
Slight (L)	<5	<1	>60	<1.5	
Moderate (M)	5–25	1–2	60–30	1.5–3.5	
Severe (S)	25–50	25	30–10	3.5–7.5	
Very severe (VS)	>50	>5	10–0	>7.5	
Degree	Supplementary indicators				
	Soil deflation thickness (cm)	Accumulative thickness (cm)	Soil deflation rate (t/ha·a)	Overload population (%)	Overload livestock (%)
Slight (L)	<5	<5	>0.5	−50 to −31	−50 to −31
Moderate (M)	5–10	5–10	0.5–1.0	−31 to 0	−31 to 0
Severe (S)	10–20	10–20	1.0–3.0	0–31	0–31
Very severe (VS)	>20	>20	>3.0	>31	>31

[a]Vegetation cover is calculated by the projection method, and the vegetation cover of the local primary landscape is regarded as 100%

occupy 25% of the area; (b) shrubs grow well, and sand mounds of different sizes appear around shrubs; (c) there is a thin layer of shifting sands on the land surface; (d) the ridges of the cultivated field are eroded, sands accumulate between ridges, and the humus layer loss in the soil is less than 50%; (e) crop yield is 50–80% of the initial stages of cultivation; and (f) shallow blowouts occur in the sandy area, but some vegetation still exists; in addition, the blowouts gradually transform without a visible steep bench.

2. Moderate aeolian desertification: (a) a distinct differentiation between eroded slopes and slip faces appears, vegetation cover is 15–30% of the original cover, and the area of shifting sand occupies 25–50%; (b) leaved shrubs cannot entirely

Fig. 1.1 Remote images (left) and field pictures (right) of different grades of aeolian desertification in the Horqin Region, Inner Mongolia, China (provided by Hanchen Duan). (**a**) Slight aeolian desertification. (**b**) Moderate aeolian desertification. (**c**) Severe aeolian desertification. (**d**) Very severe aeolian desertification

cover sand mounds, and there are shifting sands on the windward side of the sand mounds; (c) small patches of shifting sand occur on loessial farmland or land surface covered by coarse sands or gravel, but minimal vegetation still exists with a coverage of 10–30%; (d) there is obvious wind erosion on the cultivated land, less than 50% of the humus layer has been blown away, and crop yield is 50% of the initial stages of cultivation; and (e) blowouts are mostly exposed, and ridges are easy to distinguish.

3. Severe aeolian desertification: (a) sandy land is in a semifixed state, the area of shifting sands exceeds 50%, and vegetation coverage is less than 15% of the original cover; (b) gobi landscape occurs, and vegetation cover is less than 10%; (c) humus layer of the soil is eroded and almost blown away, calcic horizon is exposed, and most desertified croplands are abandoned; and (d) deflation mounds and pillars appear on the land surface.
4. Very severe aeolian desertification: (a) land loses its productivity completely; (b) a mobile sand dune landscape occurs in the sandy lands; (c) gobi landscape occurs in the gravel lands; and (d) yardangs occur in wind-eroded lands.

1.4 Conclusion

It is essential to scientifically define aeolian desertification. Different understandings will lead to considerable differences in the area and distribution of aeolian desertified land. More importantly, different perspectives will affect the places where aeolian desertification prevention measures are implemented and the choice of prevention measures. For example, treating natural dune fields as aeolian desertified land will lead to unsustainable land use methods such as large-scale afforestation in dune fields. A scientific and unified aeolian desertification discrimination index system is also essential. Achieving the global goal of Zero Land Degradation requires a scientific index system to evaluate whether the land is in the process of desertification development or reversal. Without a unified scientific standard, it is difficult to determine at a global scale whether zero land degradation has been achieved or the case is far from it. This chapter only briefly introduces the concepts and classification systems of aeolian desertification in China. A definition and evaluation system suitable for aeolian desertification on a global scale also requires the joint efforts and contribution of scientists across the world.

References

Aubreville A (1949) Climats, forêts et désertification de l'Afrique tropicale. Société d'Editions Géographiques, Maritimes et Coloniales, Paris
Carder DJ (1981) Desertification in Australia-a muddled concept. Search 12(7):218–221
Chen GT (1994) UN convention to combat desertification and definitions of desertification. J Desert Res 14(4):71(in Chinese with English abstract)
Chen GT (2001) Causes of the difference of statistic sandy desertification area in China. J Desert Res 21(2):209–212 (in Chinese with English abstract)
Chen GT (2002) Land desertification. Chemical Industry Press, Beijing (in Chinese)
China National Committee to Implement the UN Convention to Combat Desertification (CCICCD) (1994) United nations convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa. China Science and Technology Press, Beijing
Ci LJ (1995) Desertification and sandy desertification. Sci Technol Bull (8):32 (in Chinese with English abstract)
FAO, UNEP (1984). Provisional methodology for assessment and mapping of desertification. Report in Rome
Glantz MH (ed) (1977) Desertification: environmental degradation in and around arid lands. Westview Press, Boulder
Hou RZ (1973) Changes of the Mu Us Desert from vicissitude of the ancient cities along the Hongliu River course. Cult Reli (1):35–42 (in Chinese with English abstract)
UNEP (1992) World Atlas of Desertification.
Le Houerou HN (1962) Les pâturages naturels de la Tunisie aride et désertique. Inst Sces Econ Appl Tunis, Paris
Li LK (1994) My view on the Chinese translation of "desertification". World Forest Res 7(2):87–88 (in Chinese with English abstract)
Quintanilla EG (1981) Regional aspects of desertification in Peru. In: Combating desertification through integrated development, UNEP/UNEPCOM International Scientific Symposium, Abstract of Papers, Tashkent, USSR, 114–115
UN Conference on Desertification(UNCD) (1978) Round-up, plan of action and resolutions. United Nations, New York
UN Secretariat of the Conference on Desertification (1977) Desertification: an overview. In: Desertification: its causes and consequences. Pergamon Press, New York
UNCCD (2000) Desertification, global change, and sustainable development. Desertification Control Bulletin, 20: Fact Sheet 2, 10
UNCED (1992) Earth Summit Agenda 21: programme of action for sustainable development. United Nations Department for Public Information, New York

Wang T (1989) A comparative study of desertification in typical areas in Northern China. J Desert Res, 9(1):113–136 (in Chinese with English abstract)
Wang T (1991) A case study on rangeland desertification in Bashang Region, Hebei Province, Progress Report on Part 2, Desertification Application Research Programme, World Laboratory, pp 163–171
Wang T (1993) Desertification in the North China- causes, processes, trends and harness. J Agric Meteorol 45(5):691–694
Wang LX (1994) Current situation and development trend of global desertification control. World Forest Res 7(1):10–17 (in Chinese with English abstract)
Wang T (2011) Deserts and aeolian desertification in China. ELSEVIER in Amsterdam and Science Press in Beijing
Wang KF, Wang T (1989) Characteristics of study to combat desertification in Pakistan. Desert Sea 1:1–3 (in Chinese with English abstract)
Wang T, Wu W, Wang XZ (1998) Remote sensing monitoring and assessing sandy desertification: an example from the sandy desertification region of northern China. Quat Sci (2):108–118 (in Chinese with English abstract)
Wang T, Zhao HL, Xiao HL (1999) Progress in the research of desertification of China. J Desert Res 19(4):299–311 (in Chinese with English abstract)
Yi LY (2005) The area of desertification region and sandy land in China shrunk for the first time. Pratacult Sci, (7):115 (in Chinese with English abstract)
Zhu KZ (1959) Rehabilitating desert is our historical mission. China Daily 1959-8-2 (in Chinese)
Zhu ZD (1994) The status and prospect of desertification in China. Acta Geograph Sin, 61(S1): 650–659 (in Chinese with English abstract)
Zhu ZD (1999) Spatial distribution of land desertification in China. In: Zhu ZD et al (eds) Sand desert, sandy desertification, desertification and control in China. China Environmental Science Press, Beijing (in Chinese)
Zhu ZD, Chen GT (1994) Sandy desertification in China. Science Press, Beijing (in Chinese)
Zhu ZD, Liu S (1981) Aeolian desertification processes and its control regionalization in North China. China Forestry Publishing House, Beijing (in Chinese)
Zhu ZD, Wang T (1990) An analysis on the trend of land desertification in northern China during the last decade based on examples from some typical areas. Acta Geograph Sin 57(4):430–440 (in Chinese with English abstract)
Zhu ZD, Wang T (1992a) Theory and practice on sandy desertification in China. Quat Sci (2): 97–106 (in Chinese with English abstract)
Zhu ZD, Wang T (1992b) Development trend of sandy desertification in northern China. Chin Nat Geograp (1):2–3 (in Chinese with English abstract)
Zhu ZD, Wang T (1993) The trends of desertification and its rehabilitation in China. UNEP Desertificat Cont Bull 22:27–30
Zhu JF, Zhu ZD (1999) Sandy desertification control in China. China Forestry Publishing House, Beijing (in Chinese)
Zonn IS (ed) (1981) USSR/UNEP projects to combat desertification. Moscow Centre of International Projects GKNT, p 33

Chapter 2
Environmental and Ecological Setting in Northeast Asia

Tao Wang and Mandakh Nyamtseren

Abstract Northeast Asia, especially northern China and southern Mongolia, has experienced severe aeolian desertification in the past several decades and is considered a primary source region of Asian sand-dust storms. Abundant sand, strong winds, and minimal plant coverage are the three aspects that cause an area to be prone to aeolian desertification and sand-dust storms. This chapter describes the process through which abundant sand occurs (from where and how), climatic systems and climate change, and land coverage and land use change due to climate and human activities in northern China and southern Mongolia based on previous studies, climatic data, and remote sensing.

Keywords Climate change · Land use and cover · Aeolian desertification · Northern China · Mongolia

2.1 Climate of Mongolia

Its geographical location, especially remoteness from seas and oceans, high elevations, and surrounding mountain systems predetermine the harsh and distinct continental climate in Mongolia. The climate of Mongolia, therefore, is characterized by a high variability in climatic indices both in terms of temporal and spatial distributions

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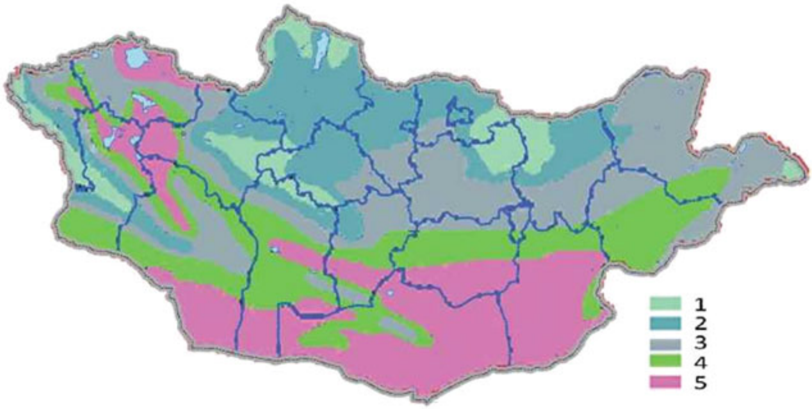

Fig. 2.1 Climatic regions of Mongolia (Jambaajamts 1989). Note: (1) Extra humid, cold region; (2) humid, temperate region; (3) subhumid, cool region; (4) semiarid, warm region; (5) arid, hot region

with high amplitudes of diurnal and seasonal temperatures and relatively low atmospheric precipitation. Over the majority of the land, the climatic index distribution follows latitudinal and altitudinal variations, and only in the easternmost corner in the Khingan Mountains are small areas of longitudinal changes observed due to the impact of the monsoon climate. According to the climate classification (Fig. 2.1), approximately 40% of the total territory is classified as arid and semiarid, and only 10–15% of the territory is classified as extra humid (Jambaajamts 1989).

Mean annual air temperatures differ by region; for instance, in the Altai, Khangai, Khentei, and Khuvsgol mountainous regions, the air temperatures vary from −2 to −4 °C, and over the large depressions and river basins, they decrease to a range of −6 to −8 °C in the southern regions; the mean annual temperatures can exceed +2 °C (Fig. 2.2). The recorded highest annual mean air temperature is 8.5 °C at the Ekhiingol station. The mean air temperatures in winter range from approximately −22 to −25 °C on average for the country. The lowest temperatures can be observed in the mountainous regions of the Altai, Khangai, Khuvsgol, and Khentei mountains and range from −30 to −34 °C. On the steppes and high plains, winter temperatures are normally between −20 and −25 °C, and it is relatively warm to the south, where temperatures range from −15 to −20 °C. The mean temperatures in summer are approximately 15 °C in the mountain regions, 15–20 °C on the plains and in the depressions, and 20–25 °C in the eastern and southern parts of the country. The long-term minimum temperature recorded in Zuungobi, Uvs aimag, was −55.3 °C, and the maximum temperature documented in Darkhan city, Darkhan-Uul aimag, was 44 ° C.

The spatial distribution of precipitation in Mongolia is very specific due to the complex impact of geographical factors, i.e., location, landforms, and surface roughness. Typically, precipitation decreases from north to south and from east to west (Fig. 2.3); however, the heterogeneity of the landforms influences the general