Catena 133 (2015) 373–384

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Horizontal wind erosion flux and potential dust emission in arid and semiarid regions of China: A major source area for East Asia dust storms

Haibing Wang [a,*], Xiaopeng Jia [a], Kuan Li [b], Yongshan Li [a]

[a] Key Laboratory of Desert and Desertification, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 260 Donggang West Road, Lanzhou, Gansu Province 730000, People's Republic of China

[b] The Inner Mongolia Autonomous Region Land Investigation and Planning Institute, 11 Xueyuan West Road, Hohhot, Inner Mongolia Autonomous Region 010010, People's Republic of China

A R T I C L E I N F O

Article history:
Received 4 December 2014
Received in revised form 17 June 2015
Accepted 17 June 2015
Available online 23 June 2015

Keywords:
Horizontal wind erosion flux
PM10 dust emission
Northern China
Dust storm
Sand trap

A B S T R A C T

Arid and semiarid regions of China are important sources of dust for storms that affect East Asia and the western Pacific Ocean. However, little is known about the process, spatial variation, and quantity of the emission and transportation of windblown sand/dust from such areas. In 2009, a large number of passive sand traps were set on different landscape surfaces across the arid and semiarid regions of China, to monitor the horizontal wind erosion flux and establish the potential of dust emission. The monitoring data suggest that the Taklamakan Desert has the greatest wind erosion flux. The mean wind erosion flux of the marginal sand seas, hinterland sand seas, Gobi-type desert, and degraded land of oases in this area is 45.07, 32.37, 31.11, and 19.83 kg day^{-1} m^{-2}, respectively. During the aeolian transport process, the mean limit of a suspended load particle size is 0.066 mm, aeolian sediment mean grain size and sorting are 0.11 mm and 1.40, respectively, and potential PM10 dust emission rate is 0.969 kg day^{-1} m^{-2}. The Qaidam Basin and Dunhuang areas and the Hexi Corridor and Alax areas also have strong wind erosion flux. The mean wind erosion flux for the Gobi-type deserts in these areas is 11.57 and 39.16 kg day^{-1} m^{-2}, respectively, while for the degraded land of oases it is 14.78 and 12.68 kg day^{-1} m^{-2}, respectively. During the aeolian sediment transport process, the mean limit of a suspended load particle size is 0.083 mm, aeolian sediment mean grain size and sorting are 0.18 mm and 1.82, respectively, and potential PM10 dust emission rate is 1.011 kg day^{-1} m^{-2}. The Mu Us sandy land, steppes of the northern Yinshan Mountains, Hunshandake sandy land and its surrounding steppes, and Horqin sandy land have the weakest wind erosion flux; the mean value of which is 10.53, 5.43, 2.88, and 1.94 kg day^{-1} m^{-2}, respectively. During the aeolian sediment transport process, the mean limit of a suspended load particle size is 0.12 mm, aeolian sediment mean grain size and sorting are 0.25 mm and 2.1, respectively, and potential PM10 dust emission rate is 0.103 kg day^{-1} m^{-2}.

1. Introduction

Aeolian processes occur in arid and semiarid regions in conjunction with windblown sand/dust activities. During the process of windblown sand/dust activity, the sand/dust particles on the land surface are released, transported, and deposited, causing land degradation, dust storms, and the formation and development of aeolian landforms (Bagnold, 1941; Bullard, 2006; Chepil, 1952; Gillette and Passi, 1988; Shao and Dong, 2006). The arid and semiarid regions of China encompass large areas of easily erodible landforms such as mobile sand seas, Gobi-type deserts, degraded land of oases, aeolian lands, and steppes. These regions are regarded as among the most important sources of dust for storms that affect East Asia and the western Pacific Ocean. Previous studies have indicated that 800 Tg of dust is emitted into the atmosphere annually from the desert regions of China, of which 30% is redeposited onto the deserts of origin, 20% is transported over continental China, and the remaining 50% falls out over the Pacific Ocean and beyond (Zhang et al., 1997). The long-range transport of dust is an important link in biogeochemical cycling between terrestrial, atmospheric, and oceanic systems (Mahowald et al., 2009; McTainsh and Strong, 2007; Okin et al., 1977; Schulz et al., 2012; Tan et al., 2011), and it has significant effects on the regional long-term radiative balance (Kinne and Pueschel, 2001; Mahowald et al., 2011; Skiles et al., 2012; Sokolik et al., 2001). Crucial to the understanding of all the effects of aeolian mineral dust from northern China on global environmental systems is the identification of dust sources, because the physical and chemical characteristics of suspended dust are strongly governed by their surface provenance.

Large-scale source areas for dust that have displayed persistent emission signatures have been detected and mapped using remote sensing data (e.g., Gao and Washington, 2009; Prospero et al., 2002; Washington et al., 2003). However, the inherent spatiotemporal

* Corresponding author.
E-mail addresses: HBWang@lzb.ac.cn (H. Wang), jiaxp@lzb.ac.cn (X. Jia), nmlikuan@126.com (K. Li), liys13@126.com (Y. Li).

http://dx.doi.org/10.1016/j.catena.2015.06.011

heterogeneity of these sources, in terms of potential controls on dust fluxes and dust chemistry, is often poorly constrained at the scale of remote sensing observations (e.g., Bullard et al., 2011; Mahowald et al., 2007). In addition, following direct measurements of total suspended particulates, and analyses of geomorphic conditions, wind environments, and dust storm records from weather stations covering all of northern China, numerous researchers have reported that significant contributions to Asian dust storms, which originate in northern China, derive from Gobi-type deserts (Sun et al., 2001; Wang et al., 2011), sandy deserts (Bory et al., 2002; Xuan and Sokolik, 2002), and piedmont alluvial fans (Derbyshire et al., 1998). However, because there is little information available on the quantity of sand transported during windblown sand/dust activities and its spatial variation within the arid and semiarid regions of China, it has not been possible to apportion the contributions from the various source regions or even define the source areas accurately.

In this study, based on field observations and the determination of the fractions of aeolian dust on the land surface and in near-surface sand flows, we characterized the horizontal wind erosion flux of the land surface in the arid and semiarid areas of northern China, and the volume of dust emitted (PM10) during windblown sand/dust processes. We also identified the major dust provenance landforms and their locations. The grain characteristics of aeolian sediment not only dictate the transport processes of the sand/dust particles, but also reflect the dynamic wind environment of the monitored regions.

2. Regional setting

In this study, we define the arid and semiarid area of northern China as the region east of 102°E, north of 34°N, and south of 44°N, which encompasses the area of interior Asia with its peripheral plateaus and mountains that act as barriers to the transport of water vapor, making it a region of extreme drought. Widely distributed over the land surface are landforms of mobile sand seas, Gobi-type deserts, degraded land of oases, aeolian lands, sandy lands, and steppes. Because of the arid climate, strong wind regime, and abundant sand supply in these areas, there is usually intense windblown sand/dust activity and frequent dust weather events. The highest levels of dust occurrence and transport of aeolian material to the western North Pacific region have been reported from these areas (e.g., Qian et al., 2002; Sun et al., 2001).

The volumes of PM10 dust emitted (Q_{PM10}) by typical landforms of seven natural regions within the arid and semiarid area of northern China, and their horizontal wind erosion flux (Ir), were monitored during windblown sand/dust processes. The locations of the sampling sites within the seven monitoring areas are shown in Fig. 1 and Table 1, and the significant spatial differences in landforms and vegetation types are shown in Fig. 2. The monitoring areas of the Taklamakan Desert (I), Gobi-type desert of the Qaidam Basin and Dunhuang region (II), and Gobi-type desert of the Hexi Corridor and Alax region (III) are representative of arid areas with extensive distributions of mobile sand seas, Gobi-type deserts, and aeolian land with low vegetation cover. The degraded land of oases on the lower reaches of inland rivers (Ta and Dong, 2006; Wang et al., 2012; Yan et al., 1998; Zhang et al., 1998) represents the belt of vegetation and dry-lake landforms affected by windblown sand and dust in regions around the sand seas and Gobi-type deserts. This landform type arises from both natural causes and human interference and it is important that it be monitored. For example, the terminal lake Gashun Nor, on the Heihe River in western Inner Mongolia, became dry in 1962, which was followed by the desiccation of both the migrating lake Lop Nor, at the terminus of the Tarim River, in 1972 (Yan et al., 1998) and in 1992 by lake Sorgo Nor (Zhang et al., 1998). The other monitoring areas of the Mu Us sandy land (IV), steppes of the northern Yinshan Mountains (V), Hunshandake sandy land and its surrounding steppes (VI), and Horqin sandy land (VII) are representative of semiarid areas. The steppes within these regions resemble Gobi-type desert because they have extensive areas of exposed surfaces that comprise coarse particles (e.g., fine gravel) above deposits of sands, silts, or clays (Cooke, 1970). However, they differ from true Gobi-type desert because their surfaces have greater vegetation cover.

3. Sampling collection and analytical methods

The horizontal wind erosion flux (Ir) of the land surface in arid and semiarid areas of northern China, and potential PM10 dust emission rates during windblown sand/dust processes, were evaluated between March 2009 and April 2011 using a network of 452 passive sand traps (Fig. 1, Table 1). We collected data during four overlapping intervals: Period 1 (8/3/2009–15/7/2009), Period 2 (10/6/2009–29/5/2010), Period 3 (29/3/2010–19/5/2010), and Period 4 (7/5/2010–29/3/2011). For each monitoring period, the first day represents the date the first station was set and the last day represents the final date of monitoring at the last station. Each sample site was labeled appropriately with the trapping date (Nm). We selected sample sites representative of different land surfaces, each with varying amounts of vegetation and soil-crust

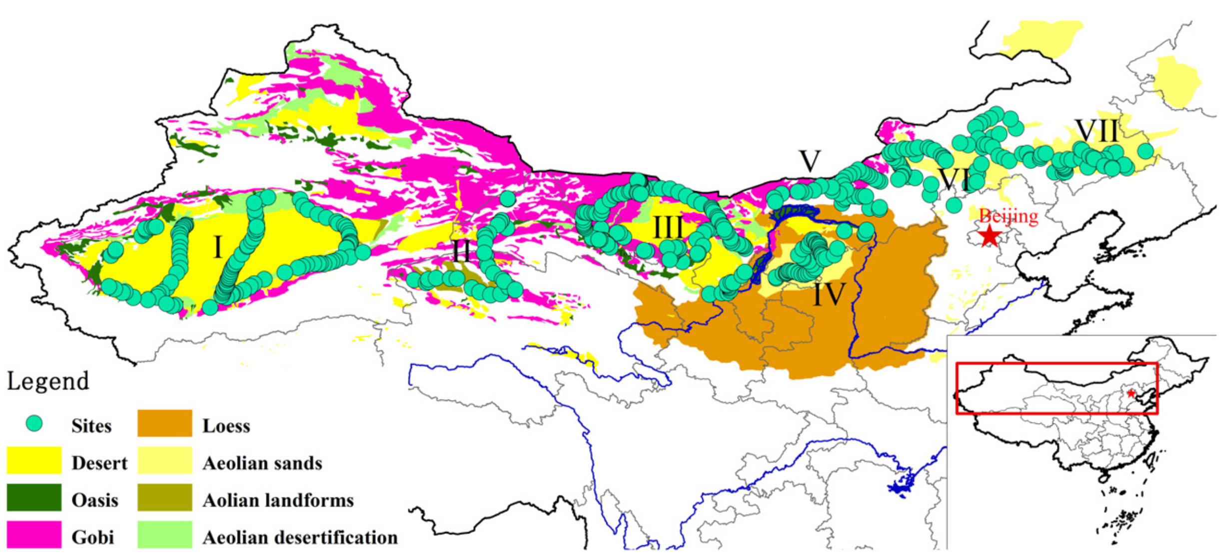

Fig. 1. Map of study area showing location of sampling sites. I: Taklamakan Desert; II: Gobi-type desert of Qaidam Basin and Dunhuang regions; III: Gobi-type desert of Hexi Corridor and Alax regions; IV: Mu Us sandy land; V: Gobi-type desert of northern Yinshan Mountains; VI: Hunshandake sandy land and Gobi-type desert; VII: Horqin sandy land.