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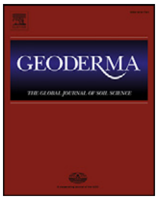

Implications of surface properties for dust emission from gravel deserts (gobis) in the Hexi Corridor

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ABSTRACT

Gravel deserts (gobis) may be primary dust sources in China, where they occupy almost the same area as sandy deserts. The obvious difference between gravel and sandy deserts is the dominant grain size in the surface sediments: fine in sandy deserts versus coarse in gravel deserts. Potential sand transport, gravel cover, and the mean grain size of the surface sediments of gravel deserts are the main factors that affect dust release. However, little data is available on these properties. In the present study, we estimated gravel cover in surface photographs using ImageJ software, determined the proportion of the total weight accounted for by gravel (diameter > 2 mm), and described the grain size distribution for study areas in the Hexi Corridor of northern China. We found statistically significant differences between the proportions of total weight as gravel among five sub-regions. This proportion ranged from 22 to 91% of the total (66 ± 17%; mean ± SD), and the proportions in most of the samples (73%) ranged from 40 to 80%. The gravel cover ranged from 15 to 87% (52 ± 17%), which was within the range in previous research that produced maximum aerodynamic roughness. The sandy material in the surface sediments was mainly medium sand, which accounted for 52.5% of the total sample. Potential sand transport was >200 vector units in most gravel deserts, and 75% of the study sites had a physical soil crust. The high gravel cover and frequency of surface crusts is likely to decrease dust emission from the gravel deserts of the Hexi Corridor.

1. Introduction

The wind-driven emission, transport, and deposition of aeolian sediments are important processes in desert areas (Kok et al., 2012). The magnitudes of these phenomena are controlled by the regional wind regime and by surface characteristics (e.g., sediment grain size distribution, soil moisture content, vegetation cover). Long-term aeolian sediment transport can carry dust in the air for hundreds or thousands of kilometers from source regions (Gillette and Walker, 1977; Zender et al., 2003, Miller et al., 2006). This dust can cause severe environmental and social problems, and has therefore attracted considerable attention from governments and researchers.

Previous research indicated that the world's dominant sources of natural mineral dust are located in the northern hemisphere, where there are many deserts and other areas of dry land (Kok et al., 2012). In Asia, dust sources include sandy and gravel deserts in southern Mongolia, the Taklimakan Desert, the Badain Jaran Desert, the Tengger Desert, and the Ulan Buh Desert (Zhang et al., 1996). In China, the major source regions are the Taklimakan Desert in western China, the arid to semi-arid region of northwestern China, and eastern Inner Mongolia (Zhang et al., 2008a; Kok et al., 2012). The dust emission from these source regions accounts for about 70% of the total Asian dust emission (Zhang and Gong, 2005). However, the specific dust sources are still being debated, mainly because of inaccurate modeling (due to inaccurate input parameters), unsound study methodology, a lack of detailed information on surface characteristics, or a combination of these factors. Some researchers think that sandy deserts are the main dust sources (Laurent et al., 2006); others think that gravel deserts are the main dust sources (Wang et al., 2011). Laurent et al. (2006) proposed that China's sandy deserts generated more dust than its gravel deserts. Dust storms have been studied by means of field observations (Jugder et al., 2011), wind tunnel studies (Wang et al., 2011, 2012), numerical modeling (Laurent et al., 2006), satellite remote sensing (Gu et al., 2003; Zhang et al., 2008a), and chemical analysis (Zhang et al., 1996, 1997). However, due to a lack of field data on the properties of desert surfaces, most previous studies mainly analyzed synoptic data on dust storms (Laurent et al., 2006; Park et al., 2010). This approach can introduce much uncertainty in efforts to identify the dust source and clarify entrainment and transport of dust materials in models. For example, the lack of field observations has created large uncertainties in key model parameters such as the surface grain size distribution,

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threshold wind velocity, and aerodynamic roughness length. Uno et al. (2006) found that the estimated dust concentration could differ by a factor of 2 to 4 in their analysis of the effects of changes in such parameters in eight dust transport models.

The area of sandy desert in northwestern China is about 56×10^4 km^2, versus about 68×10^4 km^2 for gravel desert; these areas occupy about one-third of the total land area in China and are therefore a major part of the central Asian arid region and one of the region's major dust sources. Gravel deserts are likely to be a significant dust source because of their large area, and have therefore attracted the attention of aeolian and dust researchers (Qu et al., 2001; Zhang et al., 2008a; Jugder et al., 2011; Wang et al., 2012; Qian et al., 2014). Dust emissions are usually caused by the action of strong winds acting on dry, fine, and loose soil surface materials (Pye, 1987; Cook et al., 1993) and are related to the proportion of the cover as erodible grains and the fine grain content of the surface material (Wang et al., 2012). A strong wind regime and favorable meteorological conditions (e.g., low surface soil water content, relative humidity, and precipitation) can dramatically increase the likelihood of dust storm occurrence, particularly when combined with a low gravel content in the surface materials and a low vegetation cover. In contrast, a high gravel content, high soil moisture content, a weak wind regime, and high vegetation cover can decrease the entrainment of dust (Laurent et al., 2006; Rostagno and Degorgue, 2011). Vegetation cover can decrease sediment loss by wind because it reduces the near-surface wind speed and soil erodibility, and increases the capacity for capturing windblown eroded material (Van De Ven et al., 1989; Dong et al., 1996; Leenders et al., 2011; Munson et al., 2011).

In sandy deserts, there is no doubt that the sandy surface is the main sand source (Zhang et al., 1996, 2008a). The grain size distribution in this surface (Bagnold, 1941), its soil moisture content (Chepil, 1956; McKenna–Neuman and Nickling, 1989; Bisal and Hsieh, 1996; Shao et al., 1996; Dong et al., 2007), and vegetation all control sand and dust entrainment in these deserts (Hupy, 2004). However, in gravel deserts, it is unclear whether the gravel surface is a significant dust source. In northwestern China, the gravel cover in these deserts ranges between 32 and 85% (Qian et al., 2014). Wind tunnel experiments have indicated that the gravel surface is relatively stable at gravel cover ranging from 40 to 70% (Dong et al., 2002a,b; Zhang et al., 2004), but Wang et al. (2013) recently found that high gravel cover did not necessarily decrease dust entrainment; in fact, With a total gravel coverage below 40%, wind erosion increased as the gravel cover increased. However, due to aerodynamic roughness and drag coefficients on the gravel surface, a gravel cover above 40% resulted in the surface becoming aerodynamically stable and a reduction in wind erosion (Wolfe and Nickling, 1996; Dong et al., 2002a,b). In contrast, Lyles (1988) found that when the cover of non-erodible material reached 80%, erosion of the erodible material ceased.

This summary of previous research suggests the importance of gravel cover in aeolian sediment transport. However, apart from the study of Qian et al. (2014), who studied only a small region of the Zhongyang Gravel Desert and Gashun Gravel Desert, there is little data on the distribution of gravel cover in China's desert areas. In the present study, we obtained additional data for a key desert area in northwestern China, the Hexi corridor. Based on our field study, we describe the properties of the region's gravel desert surfaces (grain size distribution, gravel cover proportion, gravel as a proportion of total weight, and the presence of a surface physical soil crust). Our first goal was to provide basic data that could be used to predict wind erosion and dust emission in these areas. Our second goal was to use the properties of the gravel surfaces to support future efforts to assess the potential dust sources in the study area in numerical models.

2. Material and methods

2.1. Study region

The Hexi Corridor lies in northwestern China (Fig. 1). The desert area is surrounded by the Qilian Mountains to the south and southwest, by the Kumtagh Desert to the west, by the Mazun Mountains, Heli

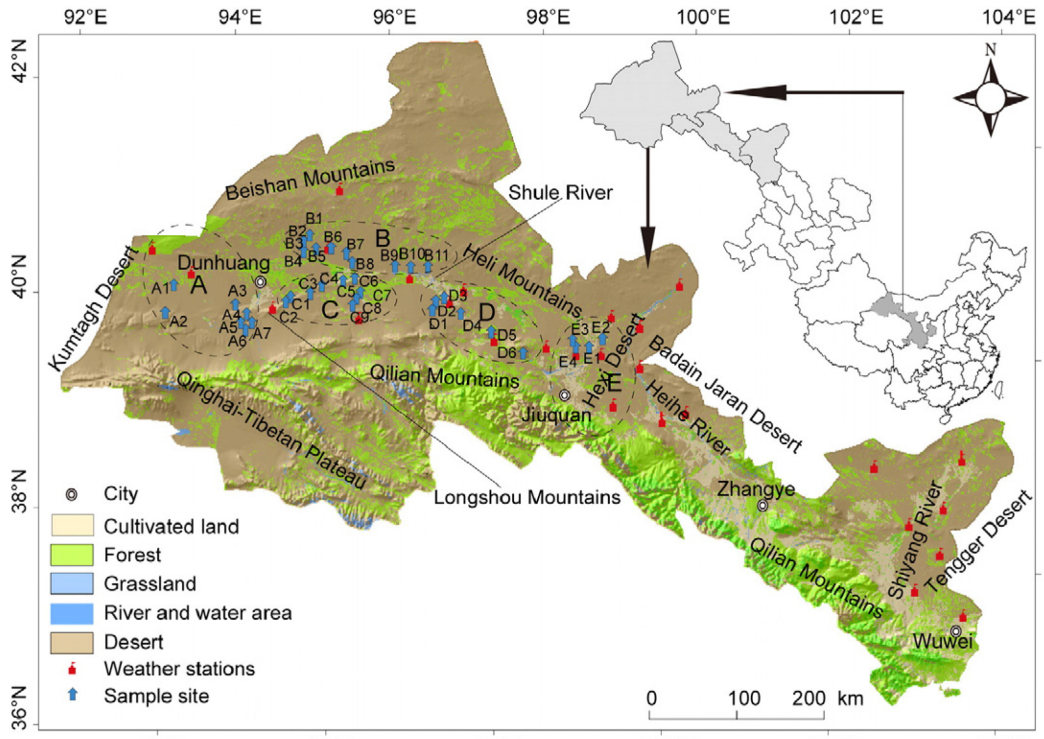

Fig. 1. Location of the Hexi Corridor in northwestern China, and locations of the weather stations, the field sample sites and of the five sub-regions of the Hexi Corridor: (A) the Kumtagh Desert, surrounding a gravel desert; (B) the northern gravel desert; (C) the southern gravel desert; (D) the Jiuquan gravel desert; and (E) the Hexi Desert, surrounding a gravel desert.