

Sand-dust storms in and around the Ordos Plateau of China as influenced by land use change and desertification

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Abstract

The occurrence of sand-dust storms induced by wind erosion is a process that accelerates land degradation and can also be considered as an indicator of desertification. Thus, it is of significance both in theory and in practice to reveal the interaction between these two phenomena. Based on data from the Ordos Plateau and its surrounding areas, a study has been made of the effect of land degradation and land use changes on sand-dust storms. In this study, we report a non-linear relationship between sand-dust storm frequency and the index of land degradation (I_d), which is defined as the percentage of the area of total land that is desertified. Using this non-linear relationship, a threshold at $I_d = 30\%$ is established such that, when $I_d < 30\%$ sand-dust storm frequency does not change with increasing I_d but when $I_d > 30\%$, sand-dust storm frequency increases rapidly. This existence of such a threshold means that sand-dust storm frequency would increase abruptly when the human-induced I_d exceeds 30%. The time series of annual number of sand-dust storm days in the neighbouring area has been compared to the time series in the annual number of strong wind days and the time series in the area of cultivated land in Yikezhao Meng, and a multi-regression equation has been established. Based on the equation, the relative contributions of the variations in land use and in annual number of strong wind days to the variation in annual number of sand-dust storm days have been estimated as 59.7% and 40.3%, respectively, indicating that the frequency of sand-dust storms may be effectively decreased by reducing the area of cultivated land and restoring the natural steppe vegetation in ecologically fragile areas in arid and semi-arid climates.

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1. Introduction

Sand-dust storms are not only weather phenomena but also geomorphic processes around which, much research has been undertaken in the context on land degradation or desertification (e.g., Zhang, 1984; Pye and Tsoar, 1991; Tucker et al., 1991; Wang et al., 1996; Xia and Yang, 1996; Fang et al., 1997; Shi et al., 2000; Wang, 2000; Reynolds and Smith, 2002). The formation of sand-dust storms depends on three conditions (Xia and Yang, 1996) involving the existence of (1) strong winds (the driving force for sand-dust erosion and transport); (2) surface material susceptible to wind erosion and transport (the material supply condition);

and (3) unstable atmospheric conditions (the local thermodynamic circumstances). The formation of sand-dust storms is associated with strong erosion by wind; when large quantities of eroded sand-dust material are transported in the atmosphere, sand-dust storms form both on- and off-site. The intensity of aeolian erosion is determined by the relationship between the erosivity of wind and the resistance of surface material to erosion. This relationship, varying with time and space, controls the temporal and spatial behaviours of sand-dust storms. Humans play an important role in the formation of sand-dust storms, usually by means of land-use and land-cover change in the areas susceptible to formation of sand-dust storms. In arid and semi-arid areas covered by loose, fine materials, following land-use and land-cover changed due to cultivation and grazing, land degradation may

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occur. Consequently, aeolian erosion is enhanced, which results in a higher frequency of sand-dust storms. More frequently occurring sand-dust storms may cause more serious loss of land cover, and by which the frequency of sand-dust storms further increases. This positive feedback mechanism may accelerate the process of land degradation or desertification. Thus, the occurrence of sand-dust storms is not only a process by which desertification is accelerated but is also an indicator of the degree of the land degradation. Therefore, a study of the relationship between sand-dust storms and land degradation is of importance not only in theory but also in the practice of sand-dust storm control. The aim of this paper is to establish the relationship between sand dust storm frequency and land use change in the Ordos Plateau region of China (Fig. 1).

2. Study area and methods

2.1. The Ordos Plateau outlines of study area

Located in the southern part of Inner Mongolia Autonomous Region and the northern part of Shaanxi Province, the Ordos Plateau and its neighboring area spans two large-scale landform units of China, the Inner Mongolian Plateau in the northwest and the Loess Plateau in the southeast. Occurring in a transitional zone of arid to semi-arid climates, mean annual precipitation varies from 250 mm to 450 mm. The northwestern part of study area is known as the Maowusu Desert, which is a desert that developed as a consequence of mismanagement in the past (Editorial Commission for Physical Geography in China, 1982). The southern part of the Maowusu Desert is typically characterized by a combination of aeolian and fluvial processes and encompasses the drainage basins of the Kuyehe, Tuweihe and Wudinghe Rivers. The region is one of the major sediment source areas of the Yellow River and belongs to the “relatively coarse sediment producing area” of the Yellow River (Chien et al.,

1980). The strong wind erosion process reflected by the frequent occurrence of sand-dust storms in winter and spring is coupled with marked water erosion processes in the loess area caused by rainstorms in summer and autumn. This provides an important mechanism for erosion and sediment production in this area (Xu, 2000). Due to human activities, land use and land cover has been subject to significant change in the past few decades, including two opposing activities, viz. the cultivation of grassland that enhances degradation and the reduction in the area of cultivated land that may reverse desertification.

2.2. Data

During the period 1985–1990, a large-scale study was conducted in the Loess Plateau region including the study area, aimed at establishing the changes in water, land and vegetation resources (Team for Integrated Scientific Investigation on the Loess Plateau, Chinese Academy of Sciences, 1992). As part of this study, land use change and its distribution in general, land degradation and the distribution of desertified land in particular, were identified. In the present study, based on data from fieldwork and from the above source, an effort has been made to establish the relationships between sand-dust storms and the changing land use and the process of desertification. These relationships, together with other research results, may help to improve environment management in this area, including controlling wind erosion and sand-dust storm disasters, which have drawn attention from the government and public in recent years.

The frequency of sand-dust storms is expressed by the annual number of sand-dust storm days, the data of which were collected by the county meteorological stations in the study area. To relate the variation in sand-dust storms to the land use change, the annual number of sand-dust storm days in Shenmu, Jingbian and Suide counties and the annual area of cultivated land in the Yikzhao Meng located in the

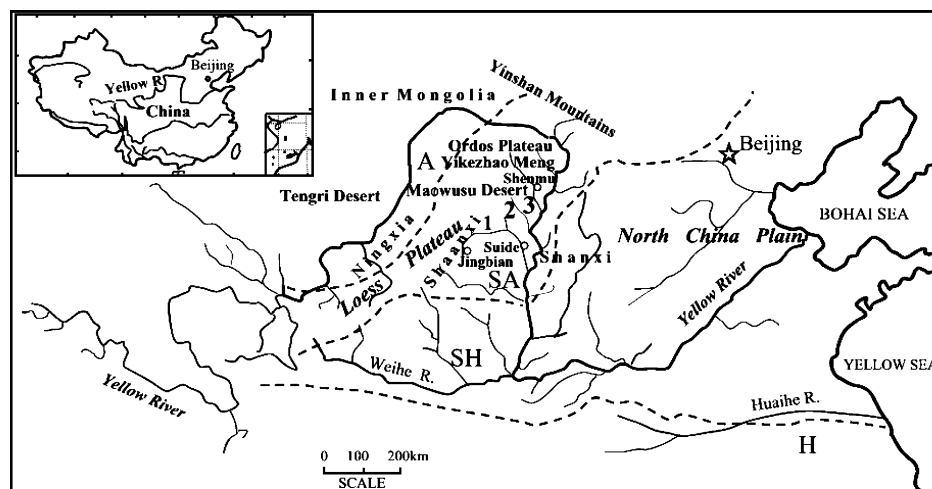


Fig. 1. A map of Yellow River basin. A: arid zone; SA: semi-arid zone; SH: sub-humid zone. 1: Wudinghe River; 2: Tuweihe River; 3: Kuyehe River.

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