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Estimation of wind erosion from construction of a railway in arid Northwest China

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ABSTRACT

A state-of-the-art wind erosion simulation model, the Wind Erosion Prediction System and the United States Environmental Protection Agency's AP 42 emission factors formula, were combined together to evaluate wind-blown dust emissions from various construction units from a railway construction project in the dry Gobi land in Northwest China. The influence of the climatic factors: temperature, precipitation, wind speed and direction, soil condition, protective measures, and construction disturbance were taken into account. Driven by daily and sub-daily climate data and using specific detailed management files, the process-based WEPS model was able to express the beginning, active, and ending phases of construction, as well as the degree of disturbance for the entire scope of a construction project. The Lanzhou-Xinjiang High-speed Railway was selected as a representative study because of the diversities of different climates, soil, and working schedule conditions that could be analyzed. Wind erosion from different working units included the building of roadbeds, bridges, plants, temporary houses, earth spoil and barrow pit areas, and vehicle transportation were calculated. The total wind erosion emissions, 7406 t, for the first construction area of section LXS-15 with a 14.877 km length was obtained for quantitative analysis. The method used is applicable for evaluating wind erosion from other complex surface disturbance projects.

1. Introduction

Wind erosion is known as a major cause for land degradation and air pollution (Tatarko, Sporcic, & Skidmore, 2013; Yang, He, Ali, Huo, & Liu, 2013). Although the natural wind erosion process has some potential positive effects, wind erosion from construction zones or disturbed sites are almost always a threat to the air quality of downwind areas (Hassan, Kumar, & Kakosimos, 2016; Neuman, Boulton, & Sanderson, 2009; Poortinga, Visser, Riksen, & Stroosnijder, 2011; Wang et al., 2015; Zobeck & Van Pelt, 2006). In dry lands with sparse vegetation, for example the vast Gobi area in central Asia, where many major projects such as railway development, road paving, and pipelines are under construction in these bare lands, soil surface disturbance from these construction activities usually result in severe erosion and a rapid increase of air particulates during the windy season (Wang, Zhou, & Dong, 2006; Zhang, Dong, Li, Qian, & Jiang, 2016). Thus, it is of great interest to know the quantity of dust generated by human disturbance from both environmental protection and human health perspectives.

Along the ancient Silk Road in western China, the 1776 km long Lanzhou-Xinjiang High-speed Railway, also named the Lanzhou-Xinjiang Second double-line Railway (LXS), is under construction which traverses throughout the arid Hexi Corridor and vast Gobi land (Cheng, Xin, Zhi, & Jiang, 2017). Unless well managed, serious wind erosion will inevitably occur during the railway construction phase. Many other large projects are also planned in similar regions including solar power stations, wind farms, mining fields, and traffic infrastructure (Zhou, Chai, & Zhang, 2011). To reduce unwanted environmental and ecological problems relating to wind eroded dust from construction sites, it is important to have a good planning tool. Such a tool must be able to estimate emissions that reflect local surface and climate conditions for various working schedules and different construction activities.

The U. S. Environmental Protection Agency (USEPA) organized a group of empirical emission factors (AP-42) (USEPA, 1995) to

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estimate wind erosion or dust emission from various sources of air pollution including vehicles travelling on unpaved roads, storage piles, heavy construction operations and industrial wind erosion (Hassan et al., 2016). These factors use averaged data and reflect long-term conditions. They are also widely used by other wind erosion models such as DUSTRAN (Shaw et al., 2008). However, there is currently no specific wind erosion model for simulating dust emissions from construction activities, mostly due to a lack of knowledge.

To predict wind erosion from construction activities, physical process-based models are desired that can simulate the changes in surface conditions representing the beginning, active, and ending phases of human disturbances, along with the deflation and movement of dust. The agricultural-oriented Wind Erosion Prediction System (WEPS) (Wagner, 2013), although limited to two dimensional and homogeneous surfaces at this time, has the potential to run on multiple fields (Gao et al., 2013), and thus provides a potential solution to this issue. In WEPS, the management files consist of a list of agricultural activities or operations, such as tillage, planting, harvesting, irrigation, etc. that are uniquely represented by an ordered list of specific physical processes and the parameter values for those processes. Therefore, WEPS is able to simulate the effects of individual agricultural activities on the land surface which influence soil erodibility (Wagner & Fox, 2013). The WEPS, especially its erosion sub-model, has been extensively validated by field measurements and wind tunnel simulations (Feng & Sharratt, 2009; Funk, Skidmore, & Hagen, 2004; Hagen, 2004; Liu, Qu, Niu, & Han, 2014).

In this work we use available methods and data to estimate wind erosion from different construction types including the construction of roadbeds, bridges, plantings, earth barrow pit and spoil areas, as well as transportation from unpaved or minimally improved gravel construction roads from a working section of the LXS project. The goal was to provide a targeted and simple applicable method for end users, which will hopefully lead to suggestions in how to improve current wind erosion models for construction site applications.

2. Material and methods

2.1. Research area and selected project

The LXS construction project was selected as a representative example because it is one of the largest construction activities within the semi-arid and arid central Asia that can cause potential severe wind erosion. Also the railway project, or specifically some parts of it, share many similarities with other important large-scale construction projects like highways and urban development, laying pipelines and mining. Thus, an estimation method developed for the railway project could likely be easily modified and adopted for other projects. This railway runs from Lanzhou in the semi-arid area westward through the extremely arid region which ends in Urumchi, Xinjiang (Fig. 1). The entire project was started in early 2010 and was finished by the end of 2014. The first work area of the LXS's15th (recorded as LXS-15 in the following text) construction section is in Yumen, near the border of Gansu and Xinjiang Provinces. This is in an extremely dry Gobi region where construction activities could easily stimulate wind erosion and has provided significant source material for large long-distance dust events in the past (Cheng et al., 2017; Qiu, Zeng, & Miao, 2001), thus the reason for selecting this region to study as a test case for evaluating this simulation estimation approach.

2.2. Division of erosion units and field work

Based on field surveys and analyzing of construction manuals, it was determined that six main potential particulate emission (erosion) units should be included: construction of roadbeds, bridges, temporary houses, earthwork areas and plantings as well as transportation to and from the selected site. All other operations that were not conducted over a loose, bare surface were ignored, but potential man-made or natural wind erosion control measures were considered.

The working schedule and duration of each subproject, methods of operation, size or area for each erosion unit was recorded in the survey and described in detail previously (Liu, 2013). Surface soils were sampled in the field and analyzed for particle size composition. Surface soil water contents were measured using a portable gauge (TZS-2, Top Instrument, Zhejiang Province, China) which detects the permittivity using a probe and reports soil water content based on the relationship between soil permittivity and water content. The speed of construction vehicles were measured by a GPS tracker, and the weight and load capacity were recorded according to the vehicles' specification information.

2.3. Estimation method

2.3.1. WEPS model

As a new generation of wind erosion simulation modeling, WEPS is superior to the previous widely adopted Wind Erosion Equation (WEQ) (Wagner, 2013). The management module in WEPS is designed to express the influence of human disturbance on the soil surface through a group of individual parameterized "processes". Each operation is represented by a unique ordered list of these "processes" that define specific physical effects on the soil,

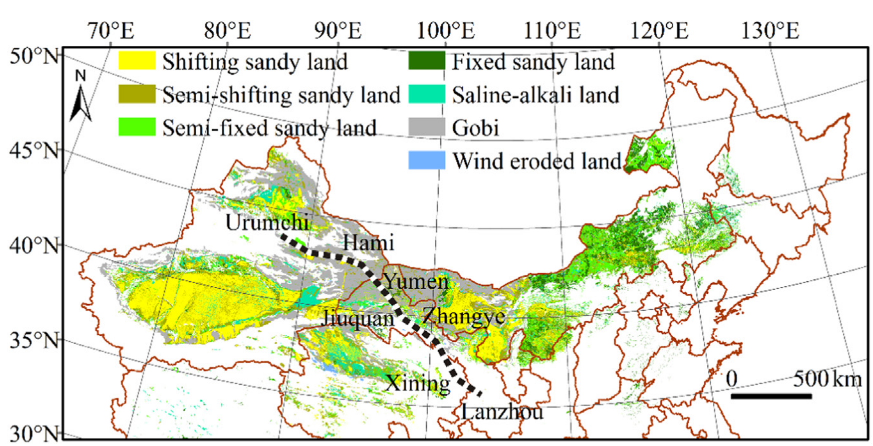

Fig. 1. Location of the LXS project and its Aeolian landform background*.