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Evaluation of two empirical wind erosion models in arid and semi-arid regions of China and the USA

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A B S T R A C T

Wind erosion models are important tools for assessing soil erodibility and identifying management practices to control erosion. The Agricultural Policy/Environmental eXtender (APEX) model and Revised Wind Erosion Equation (RWEQ) were tested using data collected from the Tarim Basin of China and Columbia Plateau of the United States of America. Adequate performance in simulating soil loss was achieved using the original APEX model and RWEQ in respectively a cotton field and desert-oasis ecotone in the Tarim Basin and winter wheat - summer fallow (WW-SF) field in the Columbia Plateau. We calibrated the APEX model and RWEQ to improve performance because both models have many empirical parameters. After calibration, both models adequately simulated soil loss from all land use types except the RWEQ from the red date orchard in the Tarim Basin. Inadequate performance of the calibrated RWEQ in the red date orchard was likely due to underestimating maximum mass transport.

1. Introduction

The arid and semi-arid regions of the Tarim Basin in China and Columbia Plateau in the United States are influenced by continental air masses that produce little precipitation and/or topographic features that intercept atmospheric moisture (Mass, 2008; Petrov, 1976). The combined influence of low precipitation, low biomass production, dry soil, and high winds contribute to the occurrence of wind erosion and poor air quality in both regions (Shao and Wang, 2003; Sharratt and Feng, 2009). Sharratt et al. (2007), for example, reported wind erosion of cropland can increase the concentration of fine particulates in the atmosphere and result in exceedance on the National Ambient Air Quality Standard for PM10 (particulate matter $\leq$10 μm in aerodynamic diameter) in the Columbia Plateau.

Wind erosion involves the movement of particles across a landscape. Soil productivity is therefore influenced by wind erosion as a result of detaching and subsequently displacing or removing fertile topsoil from the land surface. Models that simulate the detachment, transport, or loss of soil by wind have undergone an evolution of development for many decades (Wagner, 2013). Indeed, models are useful tools for predicting soil transport and loss as well as aiding in the identification of land management practices that control or mitigate erosion. One wind erosion model, the APEX model, was developed by Texas A&M University as a tool to manage farm watersheds. The APEX model is an extension of the Environmental Policy Integrated Climate (EPIC) model, thus both models use the same wind erosion algorithm to simulate wind erosion (Wang et al., 2012). Nevertheless, the wind erosion algorithm in the APEX model has undergone limited testing. Potter et al. (1998) found the EPIC model adequately simulated erosion for six of seven high wind events that caused measurable erosion of a fallow agricultural field in Alberta. The model, however, simulated erosion on three days with no measurable erosion and lacked testing across multiple seasons and broad surface conditions. Van Pelt et al. (2004) found good performance of the EPIC model in simulating erosion for eight high wind events that resulted in 0.2–1.0 kg m^{-2} of soil loss from an agricultural field in Texas. The model, however, appeared to underestimate erosion during nine wind events with an observed erosion of >1.0 kg m^{-2} and overestimated erosion during seven wind events with an observed erosion of <0.2 kg m^{-2}.

Another wind erosion model, the RWEQ, was developed by Fryrear et al. (1998) to improve the Wind Erosion Equation (WEQ)

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in simulating soil loss from agricultural fields. The WEQ was developed in the 1960's to assess annual soil loss based upon climate, soil, and vegetative cover (Woodruff and Siddoway, 1965). The RWEQ predicts short-term (daily) soil loss based upon wind, soil, and vegetative cover and orientation. Fryrear et al. (2001) noted that the RWEQ was the first wind erosion model to be tested outside the Great Plains of the United States and, while soil erodibility was key to predicting soil loss by the WEQ, wind was key to predicting soil loss by the RWEQ. Buschiazzo and Zobeck (2008) found that the RWEQ underestimated soil mass transport by 45% in a bare agriculture field and failed to predict erosion despite erosion occurring in fields subject to conventional and no tillage in Argentina. Similar underestimation of the RWEQ was found by Zobeck et al. (2001) and Van Pelt et al. (2004) at multiple sites in the United States. Youssef et al. (2012) found the RWEQ adequately predicted soil mass transport, but only after calibrating the model to local Syrian conditions. The RWEQ also poorly predicted mass transport in the Sahel (Visser et al., 2005).

Knowledge concerning the potential erodibility of soils will aid in developing management practices for the sustained use of lands in the Tarim Basin and Columbia Plateau. Pi et al. (2014a) used the Wind Erosion Prediction System (WEPS) erosion submodel to assess wind erosion in the Tarim Basin and found the submodel performed well in a desert-oasis ecotone but inadequately on agricultural land. Similar results were found by Feng and Sharratt (2009) in testing the erosion submodel on agricultural land in the Columbia Plateau. Despite these efforts to test the performance of WEPS erosion submodel, there is a need for testing other models to assess the wind erosion risk across various land use types in the Tarim Basin and Columbia Plateau. The APEX model and the RWEQ are of interest in simulating wind erosion in these regions since the two models are regarded as important tools for assessing wind erosion of agricultural lands in the United States and other regions of the world (Fryrear et al., 1998; Liu et al., 2009). Few scientists, however, have tested these models under various land cover types in arid and semi-arid regions. Testing of models under varying climates, land use types, and soils will aid in using or further developing these models for assessing wind erosion potential and developing practices for the sustained use of agricultural and natural landscapes. We are not aware that the APEX model has been tested outside North America or on land use types other than agriculture. The objective of this study was therefore to test the APEX model and the RWEQ for contrasting surface conditions associated with agricultural and native ecosystems in the Tarim Basin and agricultural ecosystems in the Columbia Plateau.

2. Materials and methods

This study was conducted in the Tarim Basin of northwestern China and in the Columbia Plateau of the Inland Pacific Northwest United States. The Tarim Basin encompasses an area of nearly 1 million km^2 and is an important agricultural region and a source of windblown dust that impacts air quality in Asia and North America (Haywood et al., 1999; Kurosaki and Mikami, 2005). Three contrasting land use types were examined in simulating wind erosion during the spring wind erosion season of 2012 and 2013. Land use types included a cotton field, red date orchard and desert-oasis ecotone and were located in Aksu County, Xinjiang Province (Fig. 1 and Table 1). The three land use types were located on soils classified as a sand with sand/silt/clay fractions being respectively 1.00/0.00/0.00 for the desert-oasis ecotone site, 0.89/0.11/0.00 for the cotton field, and 0.87/0.13/0.00 for the red date orchard. Cotton and red dates are the most common agricultural crops grown in the region. Aksu County is characterized by an arid climate with mean annual precipitation of 53 mm and mean annual temperature of

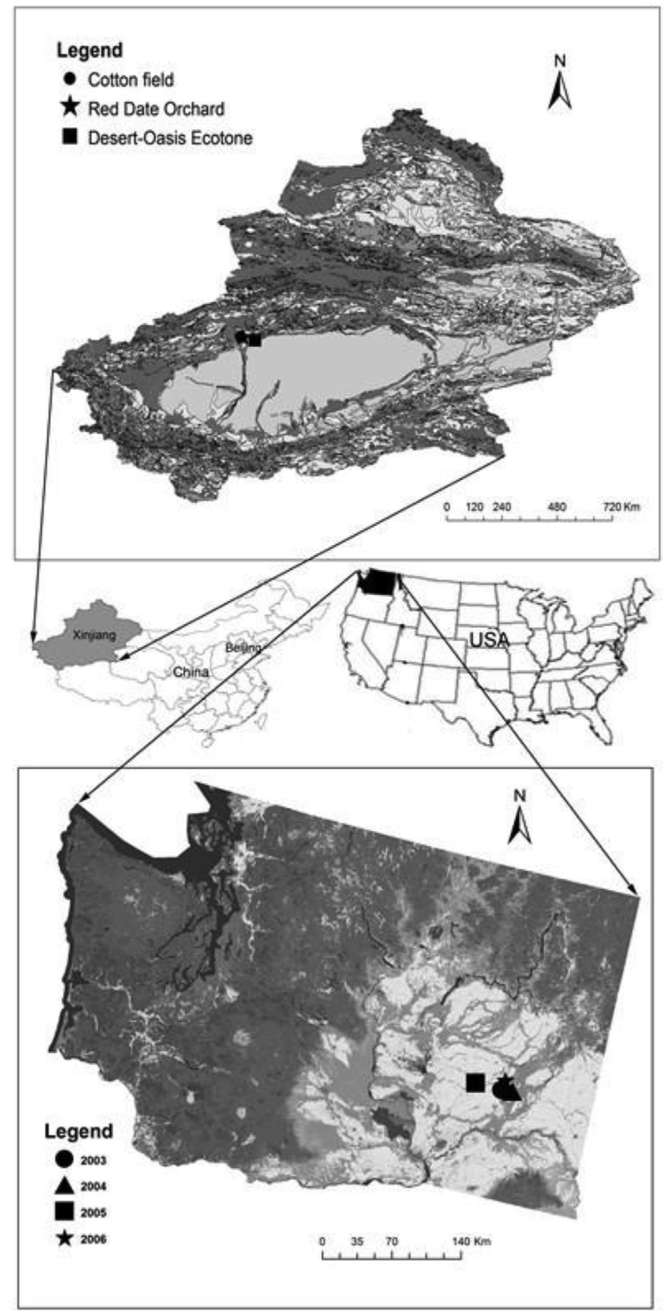

Fig. 1. Location of validation sites in the Tarim Basin, China and Columbia Plateau, USA. Shading is used to differential annual precipitation across Xinjiang Province in China and Washington state in the USA, with lighter shading denoting lower precipitation.

Table 1
Location of validation experimental sites.

Experimental site	Year	Land Use	Latitude	Longitude
Tarim Basin, China	2012, 2013	Cotton	40°37′N	80°49′E
	2012, 2013	Red Dates	40°35′N	80°51′E
	2012, 2013	Desert-Oasis	40°28′N	80°20′E
Columbia Plateau, USA	2003	Winter Wheat	45°52′N	118°29′W
	2004	Winter Wheat	46°53′N	118°17′W
	2005	Winter Wheat	46°51′N	118°39′W
	2006	Winter Wheat	46°53′N	118°26′W