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IDEAS & INNOVATIONS

Building Chinese wind data for Wind Erosion Prediction System using surrogate US data

Benli Liu, Jianjun Qu, and Larry E. Wagner

Wind erosion is a global problem, especially in arid and semiarid regions of the world, which leads to land degradation and atmosphere pollution. The process-based Wind Erosion Prediction System (WEPS), developed by the USDA, is capable of simulating the windblown soil loss with changing weather and field conditions and different man-made management scenarios (Hagen 1991; Hagen 2004; Tatarko et al. forthcoming). Erosion in WEPS is driven by stochastically generated hourly wind data by the WINDGEN program, which is more appropriate than using measured data directly, and thus hourly wind data for the entire day are needed to build the statistical database (Donk et al. 2005). The current version of WEPS contains wind data for 2,718 stations within the United States. When running WEPS, wind data from the nearest station, from a station assigned to a polygon region or interpolated from nearby stations, can be used (Wagner forthcoming). Another database, named CLIGEN, which contains other climate information, including daily temperature, precipitation, solar radiation, etc., is also needed for the WEPS simulation.

There is a great potential to extend WEPS to other countries and regions, such as China, which has a similar area, latitude location, and climate diversity to the United States. China is threatened by wind erosion on about 1.6×10^6 km^2 (6.18×10^5 mi^2) area (one-sixth of the total territory) in the north, northeast, and northwest (Hoffmann et al. 2011; Shi et al. 2004). However, wind data with sufficient time resolution are usually limited, especially in arid regions where wind erosion is serious (Lynch and Edwards 1980), which restrict the application of WEPS as well as many other environmental models. For example, many stations in China have wind data that have been recorded only four times a day, and usually only daily data are easily accessible (Donk et al. 2008). Furthermore, the hourly wind data are usually classified at a high-security level and therefore hard to obtain. Thus, it is worth investigating whether we can use wind data from the current WEPS database for locations that are outside the United States but share similar meteorological conditions.

The objective of this work was to establish a method to select the statistical wind data for Chinese locations from the existing WEPS wind database. If the chosen data can adequately represent the other locations' conditions, it would expand WEPS use for evaluating sites for soil conservation, environmental planning, and related aeolian research outside the United States.

Benli Liu is doctoral student and **Jianjun Qu** is research professor at the Dunhuang Gobi Desert Ecological and Environmental Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, Gansu, China. **Larry E. Wagner** is agricultural engineer at the Engineering and Wind Erosion Research Unit, Center for Grain and Animal Health Research, USDA Agricultural Research Service, Manhattan, Kansas.

STEPS TO BUILD THE SURROGATE WIND DATABASE

Hypothesis. Wind is driven by the air pressure difference influenced by air density, temperature, latitude location, elevation, and so on. Elevation and temperature determine air density. If the main environmental factors that affect wind in two locations are similar, then the wind activity is assumed to likely be similar. This work is based on the assumption that two places with comparable meteorological and geographical conditions, especially dynamic climate patterns, would share similar wind conditions.

The main wind erosion control factors considered in WEPS include precipitation, temporal and physical soil properties, and human management. Using wind data from a matched station and other local climate information, the simulated results would be expected to have sufficient accuracy.

Match Chinese Station with a US Climate Station. The Water Erosion Prediction Project (WEPP) (Laflen et al. 1991) model was used in this work to build the climate data for the Chinese CLIGEN stations. WEPP provides a "findmatch" tool for finding an existing US station according to its climate and geographical location characteristics from one of the approximately 2,648 US stations in the CLIGEN database shared by WEPP and WEPS (Nicks et al. 1995) and matching it to a new location. Using the least squares statistic, the matching algorithm chooses a match station based on the proximities of four factors (monthly precipitation conditional probabilities of a wet day after a wet day P[W|W], a wet day after a dry day P[W|D], elevation, and latitude) and weights them at 49%, 49%, 1% and 1%, respectively (USDA ARS 2009).

A quality-controlled daily and monthly meteorological dataset for 60-year period for 193 international exchange stations were obtained from the China Meteorological Data Sharing System. Daily maximum and minimum temperatures and precipitation for each station need to be converted to GDS (international daily temperature and precipitation data) format file using the "Text to GDS Convertor" in WEPP to build a new station record. Monthly temperature and precipitation statistics were generated by the algorithm to select a match US station from the climate database. The findmatch tool would list the ten best matches.

Then, the statistical climate data, including temperature, P(W|W), P(W|D), and the precipitation of the wet days can be adjusted to more closely match the historical monthly data because there are always missing data in the daily set that lead to the underestimation of precipitation. The statistical records for each station were arranged together to form the Chinese CLIGEN climate database.

Obtain Wind Data from a Selected US Station. After a US CLIGEN climate station is matched to each new Chinese station, the closest WINDGEN wind station to each US CLIGEN station can be selected on the WEPS wind station location map (WEPS Map Viewer). Statistical wind data, including wind direction dis-

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tribution by month, ratio of maximum to minimum hourly wind speed, hour of maximum wind speed, and cumulative percentage of wind speed at each speed level/direction, were then copied from WEPS's wind data file to the new Chinese station record. Files for all newly developed Chinese wind stations were combined together to form the surrogate Chinese WINDGEN wind database.

The matched climate station pairs share geographical similarity, including latitude, distance to the ocean, topography, etc. For example, all the matched stations for the ones in Hainan Island in the Southern China sea were Hawaiian stations.

PERFORMANCE AND APPLICATION OF THE BUILT DATABASE

Erosion Results. Multiple WEPS runs were performed for the 193 international exchange stations using the newly built Chinese climate and wind data to estimate wind erosion factors across China, keeping other inputs like soil (silt), field size of 40 × 40 m (131 × 131 ft), and management conditions (do nothing, with no actual soil disturbance activity) constant. The results were normalized to 0-100 as an erosion index (EI) to express the relative erosion potential for each station. This was done to estimate erosion potentials in other climatic areas without considering the differences due to soil type and management scenario. Thereafter, the EI map of China was built by ArcGIS software for direct analysis (figure 1).

Erosion index increases from southeast to northwest and peaks near the border between Gansu province and Xinjiang Uygur autonomous region. Stations with high EI are generally distributed in the arid steppe, Gobi, and desert regions across northern Inner Mongolia, Shanxi, Shaanxi, Ningxia, Gansu, and Xinjiang regions. Another weak high EI center is located near the border between southwest Sichuan and Yunnan Province. It is noticeable that for the most northwestern area in the Irtysh River basin, as well as for several of the westernmost stations, precipitation is relatively high, and thus EI is lower than in nearby desert places. The newly built Chinese databases successfully reflected this phenomenon.

Figure 1

Wind Erosion Prediction System–calculated erosion indexes at 193 Chinese stations.

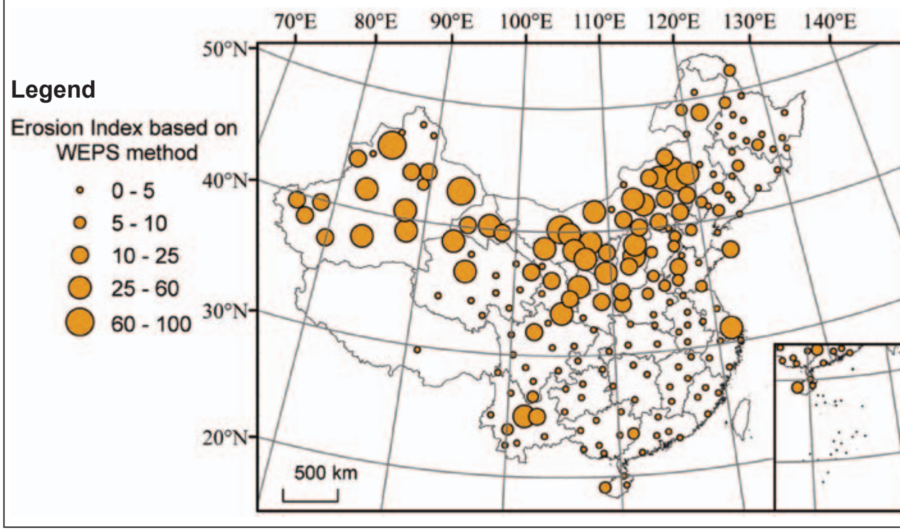
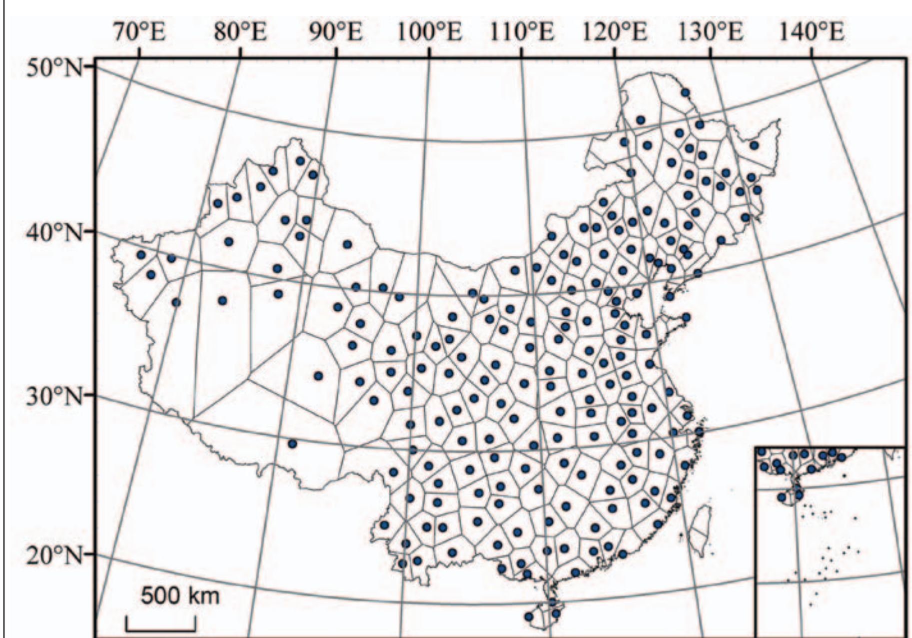


Figure 2

Thiessen polygons based on the locations of the stations.



Application of the Database. Thiessen polygons were built across the whole country to help the user find a representative station at any location (figure 2). This method is also used in current WEPS model and is suitable to the south and east regions where station density is high. Yet, for the north and west parts with fewer stations, an interpolation method is more reasonable, so a map using the Kriging interpolation method was also generated for obtaining WEPS-generated EI values at selected locations from their surrounding stations (figure 3).

Comparison with Previous Research. The created EI map was compared with an official map of wind erosion impacted areas across China (CCICCD 2006). A comparison between figure 3 and the wind erosion threatened areas in China shown in figure 4 manifests that the new Chinese CLIGEN and WINDGEN databases reflect clearly the same regions of high wind erosion, including the Khorchin sandy land in the eastern Inner Mongolia, the Badain Jaran Desert in western Inner Mongolia, the Gobi desert around the border of eastern Inner Mongolia, Gansu, and Xinjiang, and the Taklimakan Desert in the center of Xinjiang.

In addition, statistical climate data were used to validate the surrogate database. Following a method suggested by the Food and Agriculture Organization (FAO), Dong and Kang (1994) created the first wind erosivity (C) map for north and northwest China. In the FAO method (FAO 1979), wind erosivity was calculated based on simple monthly climate data, including average wind speed, potential evapotranspiration (ETP), and precipitation. ETP was estimated according to its relation to mean monthly temperature and humidity (Cheng 1980).

Monthly statistical data are easier to assess than daily data due to their lower security level, and data from more stations are available. Monthly temperature, humidity, precipitation, and wind speed data for 720 Chinese meteorological stations (2 stations at islands in South China Sea were excluded) were obtained from the China Meteorological Data Sharing System to calculate the C values according to the FAO method. Values of C for each station were also normalized to 0-100 for the convenience of comparison.

Figure 5 shows the C values calculated according to the FAO method based on the monthly statistical data from 720 climate stations across China. The main erosion centers in arid and semiarid regions fit with the WEPS-calculated EI result in figure 1. One hundred eighty six stations were shared by both the WEPS and FAO results, and the correlation coefficient (R) between EI and C for theses stations is 0.45. Thus, both the distribution and intensity of wind erosivity across China were expressed by the surrogate US wind database.

The FAO results give more details about the erosivity because of the larger number of stations. For instance, in Tibet data from 28 stations were used in the FAO estimation, but only 1 station was available for the WEPS method. However, since the FAO method considers only the amount of average monthly wind speed, precipitation, temperature, and humidity but not the threshold wind speed and daily/subdaily changes of climate factors, the EI and C values are not directly comparable at each station but represent the general pattern across the country. The WEPS-calculated EI would give a better estimation of wind erosivity across China if data from more stations were obtained.

Figure 3

Interpolated erosion index and contour map over China.

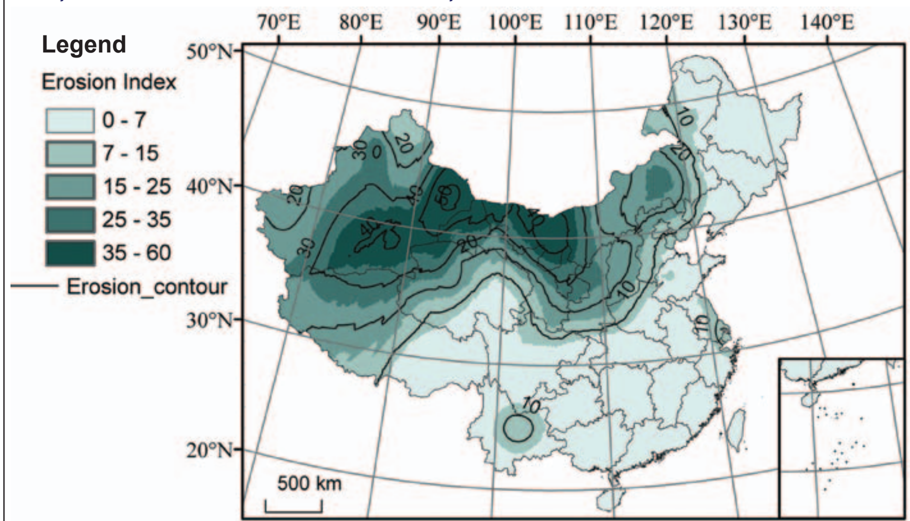


Figure 4

Wind erosion threatened areas in China (CCICCD 2006).

Limitations. Although the geographical location and diversity are similar for the two countries, at certain unique regions, especially the Qinghai-Tibet Plateau, it is still difficult to find a specific similar climate station. For 17 Chinese stations in this highest plateau in the world with an elevation higher than 2,900 m (9,514 ft), the best similar US station found was Taylor Park in Colorado at an elevation of 2,807 m (9,209 ft). Thus, the reliability of the database for this region is likely less than of the other database records.

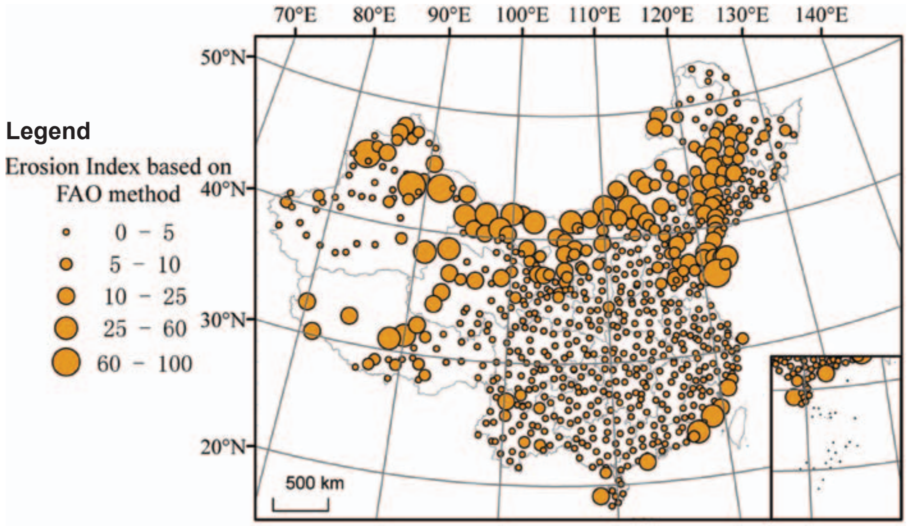
Another limitation of the wind database is the low station density, especially in the western China, which can be addressed in the future when data from more stations are available.

CONCLUSIONS

The method presented here to create a Chinese WINDGEN wind database provides the possibility to research wind

Figure 5

Wind erosivity based on the Food and Agriculture Organization estimation method for 720 stations across China.



erosion in a convenient, publicly accessible way in China and bypasses the problem of obtaining expensive and/or currently unobtainable detailed (hourly) wind data. It can be used to conduct process-based wind erosion simulations using WEPS on agriculture lands, construction sites, environmental protection scenarios, etc. with highly temporal resolution (daily and subdaily) wind data. The diverse and extensive US WINDGEN station records make it easy to find a matching station, at least for midlatitude countries.

Testing results show that the new Chinese WINDGEN wind database consisting of 193 stations successfully reflected the wind erosion character across a large territory, even though the wind data were not from meteorological records but from matched US stations for each location. Using other wind erosion control factors (including daily temperature and precipitation) from historical records, wind erosion amount and monthly change could be estimated across China with WEPS.

The database will be added to the next WEPS installation package for users' convenience. It should be updated if new hourly wind data at suitable security level are obtained for any station. In addition, results with finer spatial resolution can be obtained if additional data from more stations become available in the future.

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