Improved estimation method of soil wind erosion based on remote sensing and geographic information system in the Xinjiang Uygur Autonomous Region, China

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ABSTRACT
Detailed information pertaining to soil erosion is required to ensure eco-environment protection and economic development for Xinjiang Uygur Autonomous Region, and remote sensing and geographical information system technologies are adopted to obtain an accurate distribution of soil erosion. An improved estimation method for wind erosion is developed, which proves to be effective with an overall precision of 87.24%. The proposed model uses six critical factors: number of snow cover days, soil erodibility, aridity index, vegetation fraction, soil crust index, and wind field intensity. Results show that soil wind erosion is widely distributed throughout the Xinjiang Uygur Autonomous Region. The average erosion intensity is 0.50, which is determined to be a moderate erosion level. The wind erosion intensity increases from a slight level in the western part to a severe level in the mid-eastern part. The mean intensity of soil wind erosion for varying land use types is ranked in descending magnitude of barren or sparse vegetation, open shrubland, grassland, cropland, evergreen coniferous forest, and mixed forest. There are large differences in soil wind erosion intensities among soil types; grassland has severe wind erosion and Luvic Arenosols has the lowest erosion intensity.

KEYWORDS
Soil wind erosion; soil erodibility; soil crust index; wind field intensity; soil degradation

1. Introduction
Soil wind erosion is an important soil degradation process during late winter–early spring that occurs extensively in semi-arid and arid regions, which has major impacts on regional desertification and agriculture (Tegen et al. 2004). It occurs in relation to a combination of natural conditions (strong wind, slight precipitation, soil status, and vegetation, human activities (land use management) and threatens soil productivity and the sustainable development of rural areas (Seeger and Ries 2008). Substantial soil wind erosion not only causes loss of fine substances, organics, and nutrients, but also may even produce sandstorms and pollute the environment (Yan et al. 2011; Yan et al. 2013; Debojani et al. 2014). In recent decades, the effect of climate change has become evident, especially in the terrestrial ecosystem of semi-arid and arid regions (Tegen et al. 2004; Solomon et al. 2007). Soil wind
erosion has been exacerbated by rising temperatures and decreased precipitation in arid regions, particularly in the Xinjiang Uygur Autonomous Region of China (Feng et al. 2013). Soil wind erosion is one of the most serious eco-environmental problems in this area of northwestern China, which occurs mostly as a result of heavy grazing and dust storms (Li et al. 2004; Jiang et al. 2014). Moreover, severe wind erosion is widely distributed throughout the Xinjiang Uygur Autonomous Region, particularly in the mid-eastern region.

It is difficult to quantify sediment fluxes by wind erosion, but most of the available field measurements currently facilitate evaluations in wind erosion models (Hoffmann et al. 2008). Systematic research pertaining to soil wind erosion is currently conducted with field observations (Dong et al. 2004). Wind erosion mass follows a sigmoid curve rather than a simple exponential or power function, which can not only indicate the relationships between the wind erosion change intensity and its driving factors, but also explore how meteorological, soil, and vegetation conditions affect the susceptibility of land to wind erosion (Li et al. 2007). Wind erosion appears more frequently on thawed soil than on frozen soil, but the exact reason was ambiguous (Sharratt and Feng 2009; Webb et al. 2013). In addition, the focus of soil wind erosion has gradually been shifted from qualitative studies to semi-quantitative and quantitative wind tunnel studies (Steffens et al. 2009). Although some research achievements have been achieved relating to desertification, sandstorm, wind erosion dynamics, and wind erosion driving factors, there is still a lack of research into spatial and temporal patterns of soil wind erosion on a large-scale based on geographic information systems (GIS) and remote sensing (RS) (Buschiazzo and Zobeck 2008; Debojani et al. 2014). The enhanced aridity and loss of vegetation cover from grasslands can lead to an increase in dust storm activity (Munson et al. 2011). During the fallow phase of the rotation, the soil is very susceptible to soil erosion (Sharratt et al. 2012). However, few measurements have been reported based on GIS and RS that enable investigation of soil wind erosion in an estimation model on a large-scale.

The Xinjiang Uygur Autonomous Region is a fragile ecological zone, and this is highly related to the unsustainable utilization of barren soil and the limited water resources. The surface of the plains is mostly covered with short, simple, sparse vegetation, and the fractional coverage of the natural vegetation is typically less than 20%, although at times it reaches 0% (Xing et al. 2009). The

2. Materials and methods
2.1. Study area
The Xinjiang Uygur Autonomous Region, located in an inland arid area of Central Asia and northwest China (73°20’E–96°25’E in longitude and 34°15’N–49°10’N in latitude; Figure 1) (Li et al. 2012; Jiang et al. 2014), covers an area of over 1.66 million km² at approximately 1000 m above sea level. The study region is home to varied topography, the Junggar and Tarim Basins, and three mountain ranges, the Altay Mountains in the north, the Tienshan Mountains in the middle, and the Karakoram Mountains in the south; the Tienshan Mountains divide the region into two parts: the southern and northern parts are named as South and North Xinjiang, respectively. The area has a temperate continental arid and semi-arid climate, featured by a wide range of temperatures, strong wind, low precipitation, and low humidity. In the study region, the annual precipitation ranges from 20 to 500 and the annual temperature from 2.5–10 °C (Ping et al. 2014).

The Xinjiang Uygur Autonomous Region is a fragile ecological zone, and this is highly related to the unsustainable utilization of barren soil and the limited water resources. The surface of the plains is mostly covered with short, simple, sparse vegetation, and the fractional coverage of the natural vegetation is typically less than 20%, although at times it reaches 0% (Xing et al. 2009). The
mountainous region is characterized by abundant pasture and coniferous forest in relation to vertical zonality and high precipitation.

2.2. Data

2.2.1. Observed meteorological data
The meteorological data-sets were obtained from the Climatic Information Center of the Xinjiang Uygur Autonomous Region, China. In addition, the daily precipitation (mm), temperature (°C), monthly snow cover days (day), and wind speed (m/s) during 2010–2015 were collected from 112 meteorological stations (shown in Figure 2(in)) in and around the study region.

2.2.2. NDVI
Vegetation can increase the soil stability and reduce destructive effects on soil. The Normalized Difference Vegetation Index (NDVI), a better indicator of the vegetation activity than leaf area index, is often employed to calculate the vegetation coverage (Miao et al. 2004). The NDVI data of moderate resolution imaging spectroradiometer during 2010–2015 is organized at 1 km by 1 km with a 15-day interval, produced by the National Aeronautics and Space Administration Earth Observing System. Then, the monthly NDVI was obtained with Maximum Value Compositing (MVC). MVC, an effective NDVI smoother, is widely used to eliminate effects such as cloud contamination, atmospheric effects, solar zenith angle effects, and volcanic eruption (Li et al. 2006). The distribution of the NDVI for the study region is shown in Figure 3.

2.2.3. Soil database
Soil information of the Xinjiang Uygur Autonomous Region was acquired from the Institute of Soil Science, Chinese Academy of Sciences with a spatial resolution of 1000 m. The soil data-set is
composed of physical and chemical characteristics of topsoil (0–30 cm) and subsoil (30–100 cm), such as soil organic carbon (%), soil particle size distribution (%), clay, silt, and sand content), pH (H₂O) (−log(H+)), and calcium carbonate (%), etc. The distribution of nine typical soil types in the study region is shown in Figure 4.
2.3. Method

2.3.1. Factor standardization
Since the factors were measured in different units of measurement, standardization was needed to eliminate the unit difference among variables. Variables can be processed using Equations (1) and (2) to change them into unit-less variables (0–1).

\[ I_i = \frac{\text{Var} - \text{Var}_{\min}}{\text{Var}_{\max} - \text{Var}_{\min}} \quad \text{(Positive)}, \]

\[ I_i = \frac{\text{Var}_{\max} - \text{Var}}{\text{Var}_{\max} - \text{Var}_{\min}} \quad \text{(Negative)}, \]

where \( I_i \) is the standardized factor of Var; \( \text{Var}_{\min} \) refers to the minimum value of factor Var; \( \text{Var}_{\max} \) is the maximum value of factor Var.

2.3.2. Weight assignment method
Assigning weight for each factor according to its relative importance in the evaluation system is a great issue. A lot of researchers have used a number of different methods to assign weights to evaluation factors, such as entropy method (Guo et al. 2015), artificial neural network (Basso et al. 2000), indices weight method (Zhou et al. 2015), principle component analysis (Li et al. 2006), and analytic hierarchy process (AHP) (Park et al. 2004). In this paper, the AHP method is applied to determine the weight of each factor in a multi-criteria system, combining the field investigations and expert knowledge. The process of obtaining the weight of each factor is shown in Tables 1 and 2.

2.3.3. Comprehensive evaluation model
Multiple factors were integrated to obtain a comprehensive index using a GIS space analysis function, and the weighted linear combination method was adopted to calculate the soil wind erosion...
The comprehensive evaluation index model is described as follows:

\[
    WEI = \frac{\sum_{i=1}^{n} w_i I_i}{\sum_{i=1}^{n} w_i},
\]

where \( WEI \) is the wind erosion index; \( w_i \) refers to the weight of factor \( i \); and \( I_i \) refers to the value of evaluation factor \( i \).

### 2.4. Evaluation principle and factors

The process of soil wind erosion is generally affected by both natural factors and human activities, and it is thus essential to select appropriate indices to reflect the driving factors involved in soil wind erosion. As the typical region in the mid-latitude, the Xinjiang Uygur Autonomous Region is more sensitive to climatic warming. Because of the region’s geography, the climate is mainly controlled by high altitude air current of west wind and Mongolia high pressure with low temperature and heavy snow during the period of spring and winter (Yang et al. 2010). The eco-environment is characterized by low vegetation coverage, strong winds, strong radiation, scarce precipitation, and long sunshine duration. Therefore, after conducting field observations, we chose six critical parameters to better reflect the process of wind erosion: the number of snow cover days (Ferrick and Gatto 2005), soil erodibility (Bryan 2000), aridity index (Fisher et al. 2005), vegetation fraction (Hoffmann et al. 2008), soil crust index (SCI) (Bulygina et al. 2007), and the wind field intensity (Steffens et al. 2009).

#### 2.4.1. Number of snow cover days

Seasonal snow cover plays an important role in hydrological processes and the prevention of soil erosion. There are often more than four months of snow cover days annually in the Xinjiang Uygur Autonomous Region, and the annual average snow depth can reach 10–15 cm (Li et al. 2002). Accumulated snow can greatly reduce the area of topsoil exposed to the wind and protect the surface soil from strong winds. Therefore, the larger the snow coverage, the smaller the probability of occurrence of soil wind erosion (Wang et al. 2006). Moreover, during the melting period, the physical and chemical structures of soil particles are affected by melting snow water saturating the shallow
surface, which can increase the stability of surface soil (Laflam et al. 2004; Zhang et al. 2004). The snow cover day is defined as one when the snow depth reaches 0.5 cm. The snow cover days refer to the number of snow cover days in a year (Tejada and Gonzalez 2006). The index was calculated based on snow data derived from 112 observed meteorological data during 2010–2015 in and around the Xinjiang Uygur Autonomous Region, and then the spatial distribution of the annual number of snow cover days was obtained using the kriging interpolation method with a spatial resolution of 1000 m.

2.4.2. Soil erodibility
Soil erodibility, an essential parameter required for use in the prediction of soil erosion, is defined as the susceptibility of soils to detachment and transport by erosive agents of water or wind (Woodburn and Kozachyn 1956). Soil erodibility with a constant value is controlled by intrinsic properties of soils and can be estimated from empirical relations between the soil’s physical and chemical properties, such as the content of organic matter and its chemical composition (Zhang et al. 2004). Therefore, soil erodibility can be estimated based on surface roughness, soil structure, organic content, and soil texture (Tejada and Gonzalez 2006).

In this study, data of soil organic carbon and soil particle size distribution was used to calculate soil erodibility (Du et al. 2015; Zhang et al. 2017):

$$EF = \frac{29.9 + 0.31S_a + 0.17S_i + 0.33S_d/C_i - 2.59O_m - 0.95C_{caco3}}{100},$$

(4)

where $EF$ is the soil erodibility; $S_a$ (0.05–2 mm), $S_i$ (0.002–0.05 mm), and $C_i$ (<0.002 mm) refer to the sand fraction (%), silt fraction (%), and clay fraction (%), respectively; $O_m$ is the soil organic carbon content (%); and $C_{caco3}$ is the soil calcium carbonate content (%).

2.4.3. Aridity index
The aridity index that describes the evaporation ratio can be used to estimate the degree of aridity in an arid region or season with precipitation and reference evapotranspiration (Huo et al. 2013). It is a scientific and practical advantage to indicate a considerable deficit of surface soil water (Liu et al. 2010). The index can be used as a measurement of the amount of water available in an ecosystem within a region. Water content can affect the physical properties of the soil, which finally changes the anti-erodibility of soil (Zhou et al. 2015). The index was calculated based on daily precipitation and wind speed derived from observed meteorological data during 2010–2015, and then the spatial distribution of aridity index was obtained using the kriging interpolation method with a spatial resolution of 1000 m (Zhou et al. 2015).

$$AI = 0.16\sum T_{10oC} / P,$$

(5)

where $AI$ represents the aridity index, $\sum T_{10oC}$ is the sum of air temperatures larger than 10 °C in one year, and $P$ refers to the total precipitation during the period in which the air temperature is higher than 10 °C.

2.4.4. Wind field intensity
Soil wind erosion mostly occurs in spring and winter (from October to April of next year), and the number of strong wind days in Xinjiang Uygur Autonomous Region during the period is more than 10 times of the remaining time (Jiang et al. 2014). In semi-arid and arid regions, the often depleted and degraded soils are notably threatened due to high-erosive storm events of combined intensive rain (Cornelis and Gabriels 2003). Wind strength or speed can accelerate the weathering rate of rock or soil and influence the transport process of wind erosion materials (Zhou et al. 2015).
Therefore, wind field intensity is one of the important driving factors influencing the soil wind erosion intensity.

The critical friction velocity, mainly affected by soil physical structures and vegetation coverage, represents the wind’s capacity to restrict dust emissions from the ground’s surface (Webb et al. 2013). Erosion of soil by wind can occur when the wind velocity has reached the starting wind velocity (6 m/s). The index was obtained with daily wind speed derived from meteorological data during 2010–2015, and then the spatial distribution of wind field intensity was obtained using the kriging interpolation method with a spatial resolution of 1000 m.

2.4.5. Vegetation fraction
Vegetation cover plays an important role in intercepting raindrop or wind impact (Li et al. 2002; Hoffmann et al. 2008). The above-ground parts of plants can mitigate the erosion forces of wind, while the below-ground parts increase the soil stability and reduce destructive effects on soil. Nearly all of the previous studies have found a negative relationship between vegetation coverage and soil wind erosion (Zhang et al. 2009). Considered as one of the more important indicators of vegetation coverage, NDVI (Huete and Tucker 1991) is utilized to calculate vegetation coverage by dimidiate pixel model (Guo et al. 2015), which can eliminate the effects of clouds and soil background:

\[
FC = \frac{\text{ndvi} - \text{ndvi}_{\text{soil}}}{\text{ndvi}_{\text{veg}} - \text{ndvi}_{\text{soil}}},
\]

where FC refers to the vegetation fraction coverage; ndvi represents the value of each pixel; ndvi_{soil} is the minimum value of all pixels at a confidence level of 0.005; and ndvi_{veg} refers to the maximum value of all pixels at a confidence level of 0.995.

2.4.6. Soil crust index
The soil crust is one of the major soil structural features in many arid and semi-arid regions of the world (Hevia et al. 2007). The crusting process begins with the breakdown of aggregates and the dispersion of clay when soil is wetted or exposed to rainfall, and a thin seal or skin forms when the soil dries out after clay dispersion (Duiker et al. 2001; Hevia et al. 2007). The presence of a physical soil crust alters many characteristics of the soil surface, and this crust plays an important role in many ecosystem functions (Feng et al. 2013). In arid and semi-arid ecosystems, where wind erosion predominates over water erosion, the soil crust plays a critical role in conserving soil resources (Zhang et al. 2004). The influence of the crust on erosion has been noted for a long time in many arid regions (Veihie 2002).

In this study, the SCI was calculated using data of soil organic carbon and soil particle size distribution. The equation is as follows (Du et al. 2015):

\[
SCI = \frac{1}{1 + 0.0066 \times C_l^2 + 0.021 \times O_m^2},
\]

where SCI is the soil crust index; \(C_l\) (<0.002 mm) refers to the clay fraction (%); and \(O_m\) is the soil organic carbon content (%).

3. Results
3.1. Classification of wind erosion and accuracy assessment
In this study, the soil wind erosion intensity index of the Xinjiang Uygur Autonomous Region during 2010–2015 was calculated based on the ArcGIS 10.3 combined with the comprehensive evaluation model. In order to facilitate the analysis of the spatial patterns of soil wind erosion, the wind
erosion intensity was then divided into five categories with the method of Natural Breaks based on the chart histogram of wind erosion intensity combined with field observation data (Jenks 1967; Xu 2006): slight erosion (WEI < 0.33), mild erosion (0.33 < WEI < 0.44), moderate erosion (0.44 < WEI < 0.53), intensive erosion (0.53 < WEI < 0.63), and severe erosion (WEI > 0.63). The spatial patterns of soil wind erosion during 2010–2015 are shown in Figure 5.

In this paper, the basic error matrix (Equations (8) and (9); Guo et al. 2015) was utilized to test the accuracy of the estimated results:

\[
p_{i+} = \sum_{j=1}^{n} P_{ij},
\]

\[
p_{+j} = \sum_{i=1}^{n} P_{ij},
\]

where \( n \) represents the number of categories, \( P_{ij} \) is the number of the evaluated category \( i \) and the field survey category \( j \) that both occur, \( P_{i+} \) is the sum of the evaluated category \( i \), and \( P_{+j} \) is the sum of the field survey category \( j \).

In order to test the accuracy of the evaluated results, the precision index and the basic error matrices (Equations (8) and (9); Guo et al. 2015) were adopted. The data of field-observed wind erosion intensities was derived from the First National Census for Soil and Water conservation, which was composed of erosion rate (t/km² a⁻¹) and soil loss thickness (mm/a). To confirm the validity of the field-observation points in 2012, we chose 243 sites from regions with different geographical characteristics. According to the ‘Classification criteria for soil-erosion intensities (SL190-2007)’, the field-observed wind erosion intensities were categorized (Table 3).

Then, the error matrix of the field survey and evaluated erosion category are shown in Table 4.
From Table 5, it can be seen that the precision of user accuracy and the cartographic precision of all categories range from 0.79 to 0.93 and 0.77 to 0.91, respectively. Therefore, the field-observation results are overall in agreement with the evaluated erosion levels, and this is indicated by an overall precision of 87.24% for cartographic accuracy. This precision is 6.17% and 3.03% better than that presented in our previous studies, respectively (Zhou et al. 2015; Zhou et al. 2016). However, there is slight difference in the evaluation accuracy of different wind erosion categories: slight erosion shows the best precision (0.91), followed by mild erosion (0.89), while the accuracies of severe (0.81) and moderate erosion (0.77) are much lower. The reason lies in the fact that the field-observation points in the severe and moderate erosion regions are fewer, which affects the accuracy of the evaluation results. In conclusion, the overall evaluation accuracy of the soil wind erosion model established in this research has good applicability in the Xinjiang Uygur Autonomous Region.

### 3.2. Spatial differentiations of soil wind erosion during 2010–2015

As shown in Figure 6, soil wind erosion exists widely over the Xinjiang Uygur Autonomous Region (over an area of 146.22 km²). Soil wind erosion was continuously distributed in the eastern and southern parts, including the areas of Hami, Turpan, Korla, and Hotan. In addition, zones with no erosion or slight erosion were mainly concentrated in the western part of the Xinjiang Uygur Autonomous Region, in areas such as northern Altay, Bole, Yining, and southern Tacheng.

Of all categories of wind erosion intensity during 2010–2015, the moderate erosion zone covered the largest area of 38.41 × 10⁴ km², and this mainly covers southern Hotan, northern Turpan, and southern Korla. The intensive erosion zone covered the second largest area of 37 × 10⁴ km², spanning areas such as southern Altay, Hami, and southern Turpan. However, the slight erosion zone covered the smallest area of 16.40 × 10⁴ km², and was mostly concentrated in Yining, northern Tacheng, Bole, and northern Altay. Finally, the severe erosion zone covered an area of 20.33 × 10⁴ km².
4. Discussion

4.1. Improvement of the wind erosion model for the Xinjiang Uygur Autonomous Region

Wind erosion commonly occurs in arid and semi-arid regions where vegetative cover is sparse and does not sufficiently protect soils. The Xinjiang Uygur Autonomous Region has a semi-arid steppe climate. Wind erosion and dust storms are commonly occurring phenomena. However, limited research has been conducted on this (both in China and internationally) (Erpul et al. 2008), and compared with water erosion studies, those on soil wind erosion based on GIS and RS are few.

In this paper, we have developed an improved evaluation model of soil wind erosion, which is composed of the number of snow cover days, soil erodibility, aridity index, vegetation fraction, SCI, and wind field intensity, fully considering the unique characteristics of climate and geographical environment. Accuracy assessment of the evaluation in this paper has been improved by 6.17% and 3.03% than that presented in our previous studies in Inner Mongolia, respectively (Zhou et al. 2015; Zhou et al. 2016). Therefore, it is suitable for obtaining dynamic information of soil wind erosion over a large-scale region.

4.2. Relationship between wind erosion and land use types

Land cover increases ground roughness and friction rate and significantly affects the process of soil wind erosion because it protects the earth’s surface from air currents (Hoffmann et al. 2008). Therefore, the friction rate and resistance to near-ground air currents increase when the vegetation fraction is larger and the intensity of soil wind erosion is lighter (Lafond et al. 2009).

To explore the relationship between wind soil erosion and land use types, we chose six typical land use types: evergreen coniferous forest (ECF), mixed forest (MF), open shrubland (OS), grassland (GL), cropland (CL), and barren or sparse vegetation (BSV). In Figure 7, the top of box represents the minimum value of wind erosion intensity for each land use type, the bottom of box refers to the value of standard deviation, the top of line represents the maximum value, and the black square refers to the mean value of wind erosion intensity. The results show that the mean ranked intensity of soil wind erosion occurs in descending magnitude in a sequence of BSV, OS, GL, CL, ECF, and MF. BSV has a low ground surface roughness and friction rate and a low capacity against wind erosion (Battany and Grismer 2000), and thus the erosion intensity of BSV is the largest with a mean value of 0.56; this is classified as intensive erosion. BSV is found mainly in the mid-eastern part, where there is scarce precipitation. It is known that scarce precipitation, high temperatures, and human activities such as irrigation and overgrazing have a considerable influence on the
Such factors decrease the vegetation coverage and available water resource and destroy the physical structures of the topsoil. When the surface soil layer is loose and dry, it is then liable to soil wind erosion under the effects of frequent and strong winds (Webb et al. 2013).

The fluctuation range and standard deviation of erosion intensity for ECF and MF are the smallest because these land use types are distributed in the western part where there is high vegetation coverage and abundant precipitation. In contrast, there were larger fluctuation ranges in the erosion intensity of GL and BSV due to the wide distribution and low vegetation coverage of these land use types.

4.3. Relationship between wind erosion and soil types

Soil wind erosion is a result of an interaction between external driving forces and surface soil substances (Tejada and Gonzalez 2006). There is a great difference in the soil erodibility of varying soil types because soil erodibility is significantly affected by the physical and chemical structure of the top-layer soil, such as the organic content, calcium carbonate content, and soil texture (Hevia et al. 2007).

To analyse the effects of soil type on soil wind erosion, nine typical soil types (Luvic Arenosols (LA), Gleyic Cambisols, Eutric Fluvisols, Chromic Luvisols (CL), Eutric Cambisols (EC), Haplic Luvisols, Dystric Gleysols (DG), Ferric Podzols, and Gleyic Luvisols (GL)) were chosen. In Figure 8,
the top of box represents the minimum value of wind erosion intensity for each land use type, the bottom of box refers to the value of standard deviation, the top of line represents the maximum value, and the black square refers to the mean value of wind erosion intensity. The results show that there are large differences in soil wind erosion intensity among the soil types which are related to differences in soil properties. The erosion intensity of GL was the largest with a mean value of 0.73 (severe erosion) followed by that of EC with a mean value of 0.61. The soil crust and erodibility of a soil depend mainly on its physical properties, such as stable aggregates, bulk density, and infiltration rate (Duiker et al. 2001), and the organic content, calcium carbonate content, and the distribution of particle sizes in the top-layer of soil can largely affect the soil’s resilience against wind erosion (Jin et al. 2009). For GL and EC, the content percentages of clay, organic matter, and calcium carbonate were smaller, and thus these two soil types have a low resilience to soil wind erosion. In contrast, DG and LA had smaller mean erosion intensities with values of 0.32 and 0.26, respectively. The organic content of DG and LA was abundant, and this increases the ability of these soil types to resist soil wind erosion (Tejada and Gonzalez 2006). In addition, the clay content with a particle size of 0–1 mm is important in determining soil erodibility (Miao et al. 2004), and soil erodibility decreases with an increase in clay content.

5. Conclusion

Based on data obtained from GIS and RS, this paper introduces the SCI to establish an improved estimation model of soil wind erosion in the Xinjiang Uygur Autonomous Region, which fully considers the regional features and the driving factors of wind erosion. Precision testing using field-sampling data shows that the new estimation model of wind erosion has strong operationality and practicability. The main conclusions are as follows:

(1) Throughout the Xinjiang Uygur Autonomous Region (an area of 146.22 km²), soil wind erosion occurs widely (in 89.92% of the study region). The average erosion intensity was determined as 0.50, which was categorized as belonging to the moderate erosion category. There was a decreased trend in erosion intensity from the western to eastern regions.

(2) Varying land use types undergo different wind erosion intensities. The mean intensity of soil wind erosion was ranked in descending magnitude in the sequence of BSV, OS, GL, CL, ECF, and MF. These spatial patterns of erosion intensity for different land use types are related to the vegetation coverage and ground roughness, factors that protect the surface soil from strong winds.

(3) The soil types showed large differences in associated soil wind erosion intensities in relation to differences in their physical and chemical properties. The erosion intensity of GL was the largest with a mean value of 0.73 and LA showed the smallest mean erosion intensity with a value of 0.26.

However, it is considered that further studies are necessary to clarify the mechanisms underlying the process of soil wind erosion and to strengthen the precision of the evaluation process.

Disclosure statement

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