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Wind Erosion Characteristics of Degraded Grassland Under Different Management in Xilin River Basin

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Abstract. This study focused on the natural grassland that was not eaten by livestock in the degraded grassland of Xilin River Basin, and the grazing grassland that was heavily eaten by livestock with frequent human activities. Under the enclosure management, Mongolian agrograss + Melilotus clover was allocated to grassland, Mongolian agrograss + alfalfa was allocated to grassland, and brome without awning + Melilotus clover was allocated to grassland. Wind erosion characteristics of brome sans brome + alfalfa were studied under six management modes. The results showed that: (1) The wind speed profiles of different grassland management methods showed basically the same pattern, which showed that the wind speed increased with the increase of height. The wind speed profiles of artificial grassland A and D showed an "S" shaped curve, while the wind speed profiles of the other four grassland management methods showed A "J" shaped curve. (2) The relationship between the wind speed and the height from the ground was an exponential function, and the correlation coefficients R^2 of the fitting equations of the wind speed and the height from the ground were all above 0.95. The fitting degree of the two equations was good, and the measured results matched well with the fitting equations. (3) The surface roughness of human-managed grassland A was the highest, and its average roughness was 61.84%, 117.01%, 3.71%, 65.68% and 315.03% higher than that of the other five types of grassland, respectively. The surface roughness of human-managed grassland was significantly higher than that of grazing grassland, which was helpful to improve the grassland surface roughness. Then the erosion of surface soil reduced by the process of sand flow.

Keywords. Different management modes, deteriorated grassland, wind erosion

1. Introduction

China's grassland area accounts for 12.5% of the world's grassland area, about 3.7×109 hm^2, and it is widely distributed, covering 266 banner counties in China, accounting for about 40% of the country's total land area [1]. Among them, Inner Mongolia's grassland area is about 7.9×107 hm^2. However, in the context of global warming, precipitation in several major grassland ecosystem distribution areas such as xilingol steppe, horqin grassland and hulunbuir steppe and even in the whole Inner Mongolia decreased [2-5] while annual average temperature increased [6-10]. This change breaks the special

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requirements of grassland for water and heat conditions, and shakes the stability of grassland ecosystem. In addition, human overgrazing [11], over-cutting and over-cutting, farmland reclamation and grabbing of groundwater have resulted in large-scale grassland degradation mainly desertification in Inner Mongolia [11-14]. And spread at a desertification rate of 6.67×10^5 hm^2a^{-1} [15, 16].

Xilingol grassland, as the largest grassland in Inner Mongolia, plays a very important ecological role in water conservation, soil fixation and sand fixation, and air purification. It is an important ecological barrier in northern China and an important agricultural and storage industry circle in Inner Mongolia, providing strong support for the economic development of Inner Mongolia. The stability of grassland ecosystem and the sustainable utilization of grassland in Xilingol are not only related to the ecological security of north China and even the whole country, but also the basic guarantee for the prosperity of local economy and the stability of border area.

In this paper, the effects of three different management measures and four reseeding configurations on the wind erosion process of grassland in Xilin River basin were studied, so as to find effective solutions for preventing and controlling grassland degradation and rationally utilizing, managing and constructing grassland in Xilin River Basin. It provides scientific basis for the construction of grassland ecological security in Xilin River basin.

2. Overview and Research Methods of the Study Area

2.1. Overview of the Study Area

Xilin River basin is located in the central and eastern part of Inner Mongolia Plateau. The study area is located in Xilinhe Reservoir, Xilinhe River Basin, Inner Mongolia, and its geographical coordinates are 115°13'-117°06'E and 43°02'-44°52'N. It is the main inland river in the middle and eastern part of Inner Mongolia Plateau, with a total basin area of about 3900 km^2. Xilin River basin is adjacent to zhaomeng basalt plateau in the south, and is located in the western foothill of Daxing'an Mountains in the east and Chahar Hills in the north. The overall terrain of Xilin River basin rises gradually from northwest to southeast, with an average elevation of 1200m.

2.2. Research Methods

2.2.1. Plot Setting

In the experiment, the natural grassland, grazing grassland and human-managed grassland were all selected with the same slope direction, and the slope was about 10°. Human-managed grassland was selected in the grazing grassland area. Plowing and planting grass seeds were conducted in this area in March 2021. The grass species suitable for local growth and having obvious effects on vegetation community restoration and soil improvement were selected for planting Mongolian agrograss, Brome without miscanthus, alfalfa and Sweet clover. The planting size was 1 kg/Mu for legume and 0.75 kg/Mu for gramineae, and the combination of legume and gramineae was used to form the four-planting allocation mode. A was Mongolian ice grass+Sweet clover, B was Mongolian ice grass+alfalfa, C was brome sans fronted+Sweet clover, D was brome sans fronted + alfalfa.

2.2.2. Research Technique

(1) Determination of starting wind speed:

HOBO small weather station and sand meter were used to measure the starting wind speed in the test area. HOBO small weather station and sand meter were set in the center of the test area in windy weather, and the recording time was set as 1 s. A white paper board with double-sided adhesive was placed 40 cm above the ground. When the wind speed was less than 2 m/s, the double-sided adhesive surface paper was removed, and the time was recorded when particles were stuck on the white paper board. Compared with the natural wind speed measured at HOBO small weather station, this wind speed is the starting wind speed. Multiple data show that the starting wind speed in the test area is in the range of 4.8-6.5 m/s. Due to different grassland surface vegetation conditions under different management modes, 4.8 m/s is used as the starting wind speed in the test area.

(2) Determination of wind speed profile:

Wind speed profile refers to the distribution curve of wind speed with height. In this experiment, HOBO small weather station was used to collect wind speed data. Five heights were set for wind speed measurement, with wind cup heights of 20 cm, 50 cm, 100 cm, 150 cm and 200 cm respectively.

(3) Calculation method of surface roughness:

Surface roughness refers to the height when the surface wind speed is zero, which is one of the important indexes to measure the degree of wind erosion. When the wind speed at two heights is known, the surface roughness can be calculated by the following formula.

$$\lg z_0 = (\lg z_2 - A \lg z_1)/(1 - A)$$

where, z_0 is the surface roughness; Z_1 and Z_2 are arbitrary two heights (cm). A is the ratio of the corresponding wind speed u_2 and u_1 at z_2 and z_1 heights.

In this test, surface roughness was calculated by taking wind speed at two heights 50 cm and 200 cm from the surface in each test area.

(4) Determination of sediment transport:

When studying the characteristics of wind erosion, the distribution of sediment transport along the height is an important factor to discuss the aeolian sand movement. According to the condition that the ground length along the main wind direction should be larger than the critical ground length at the installation position of the aeometer, the aeometer is arranged. According to the local meteorological data, the main wind direction in this area in April and May is northwest, so the three sampling points are shown as Figure 1.

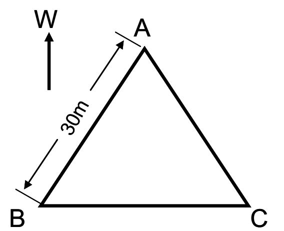

Figure 1. Set ShaYi layout diagram.

2.2.3. Data Analysis

Excel 2010 and SAS17.0 were used for data collation and statistical analysis.

3. Results and Discussion

3.1. Changes of Grassland Wind Speed Profile under Different Management Methods

From Figure 2, it can be concluded that the different management approaches the grass near ground wind speed profile change law, are based on wind speed increases with height, but artificial grassland management A grassland and artificial management D near ground wind speed profile changes than the other four kinds of management way, the change of the wind speed profile is more complex, the grass is "S" type change, wind speed at 20-50 cm significantly increased, The wind speed increases slowly at 50-100 cm, but continues to increase at 100-200 cm, but the change tends to be gentle. The near-ground wind speed of human-managed grassland B, human-managed grassland C, natural grassland and grazing grassland all shows a j-shaped change with the change of height, that is, the wind speed changes significantly with the increase of height below 50 cm. The increasing range of wind speed above 50 cm decreases with the increase of height. The average wind speed at each height of artificial management grassland A was 1.93 m/s, 3.14 m/s, 3.36 m/s, 3.77 m/s and 4.30 m/s respectively, and the wind speed increased by 62.65%, 11.32%, 21.23% and 27.44% respectively. The average wind speed at each height of human-managed grassland D was 2.29 m/s, 3.38 m/s, 3.71 /s, 4.34 m/s and 4.87 m/s respectively, and the wind speed increased by 47.52%, 10.00%, 16.82% and 12.18% respectively. From the increase of wind speed, it can be seen that the increase of wind speed decreases significantly in the height range of 50-100 cm. The average wind speed at 20 cm height of grassland under six different management modes is as follows: 1.93 m/s (artificial management of grassland A), 2.81 m/s (artificial management of grassland B), 3.23 m/s (artificial management of grassland C), 2.29 m/s (artificial management of grassland D), 3.52 m/s (natural grassland), 4.15 m/s (grazing grassland). The average wind speed at 20 cm of artificial management grassland A was 31.22%, 40.19%, 15.68%, 45.25% and 53.52% lower than that of the other five different management grassland, respectively.

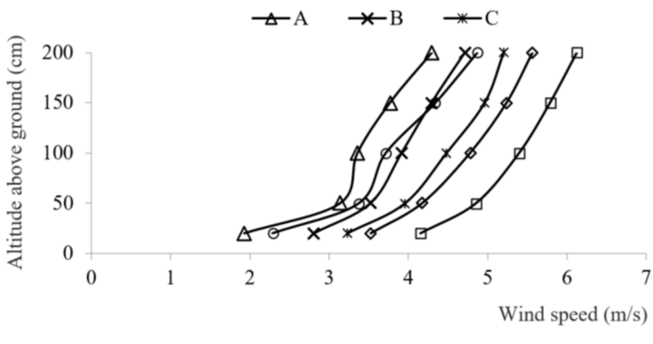

Figure 2. Different management approaches the grass wind velocity profile changes.

By fitting the relationship between wind speed and height of grassland under six different management modes, Table 1 can be obtained. It can be seen from the table that the fitting function of wind speed and height conforms to $y=ae^{bx}$ function, and the correlation coefficient R^2 is above 0.95, indicating high correlation. The fitting equation of wind speed and height in artificially managed grassland A is $y= 2.678e^{1.024x}$, and the correlation coefficient R^2 is 0.955. The fitting equation of wind speed and height in artificially managed grassland B is $y=0.631e^{1.253x}$, and the correlation coefficient R^2 is 0.981. The fitting equation of wind speed and height in artificially managed grassland C is $y= 0.495e^{1.160x}$, and the correlation coefficient R^2 is 0.994. The fitting equation of wind speed and height in artificially managed grassland D is $y=2.503e^{0.927x}$, and the correlation coefficient R^2 is 0.970. The fitting equation of wind speed and height in natural grassland is $y=0.423e^{1.121x}$, and the correlation coefficient R^2 is 0.989; the fitting equation of wind speed and height in grazing grassland is $y= 0.1551e^{1.182x}$, and the correlation coefficient R^2 is 0.994. By analyzing the fitting function and correlation coefficient of the two, it can be concluded that wind speed and height are in a positive proportion. Coefficient *a* and *b* will affect the size of the wind speed, *b* found by comparing coefficient, different management approaches the grass wind speed profile fitting function between *b* values were similar, while a large difference between two values, artificial grass *a* and human management in grassland D fitting function coefficient of 2.678 and 2.503 respectively, the value of the coefficient in the rest of the four groups function. This indicates that the grassland wind speed is greatly affected by coefficient A, and the fitting degree of the function is lower than that of the relationship function between grassland wind speed and height of the other four management modes.

Table 1. Different management approaches the grass wind speed profile regression equation.

Supervisor mode	Fitted equation	Correlation index
Artificial management of grassland A	$y = 2.678e^{1.024x}$	$R^2 = 0.955$
Artificial management of grassland B	$y = 0.631e^{1.253x}$	$R^2 = 0.981$
Artificial management of grassland C	$y = 0.495e^{1.160x}$	$R^2 = 0.994$
Artificial management of grassland D	$y = 2.503e^{0.927x}$	$R^2 = 0.970$
Natural grassland	$y = 0.423e^{1.121x}$	$R^2 = 0.989$
Grazing grassland	$y = 0.155e^{1.182x}$	$R^2 = 0.994$

3.2. Changes of Surface Roughness Characteristics of Grassland under Different Management Methods

This study selected six different management style grass 50 cm and 200 cm in adjacent and representative type of wind speed 8 groups of wind speed data for the calculation of surface roughness, in each group respectively the surface roughness will be average 8 sets of data after data processing, get a different management style grass average roughness, are made in the analysis below average roughness is analyzed.

By analyzing Tables 2-7, it can be concluded that the relationship of surface roughness of grassland under different management modes in 6 is as follows: The average roughness of human-managed grassland A, human-managed grassland D, human-managed grassland B, natural grazing grassland C, and grazing grassland was 1.411 cm, 0.872 cm and 0.650 cm respectively. The average roughness of D, natural and grazing grassland was 1.361 cm, 0.852 cm and 0.340 cm respectively. The average roughness of artificial management grassland A was 61.84%, 117.01%, 3.71%, 65.68% and 315.03% higher than that of the other five types of management grassland, respectively. The analysis showed that the surface roughness of artificial management grassland was significantly higher than that of grazing grassland. Prove fences for nurture and grass planting management measures to improve the underlying surface condition, and grazing land due to eating animals, tourists tramples all year round, and make the vegetation destroyed, and the recovery of vegetation community is a slow process for a long time, so the grazing grassland and natural grassland grass surface roughness, surface roughness than artificial management so when the sand flow of transit. As well in the management of grassland vegetation community structure to the wind speed is weaken, slow effect, further reduce the wind erosion damage to the grassland soil, and through the study found that the surface roughness of grazing grassland underlying surface conditions for transit wind speed cannot have obvious weakening effect, so the grazing grassland by the wind erosion is more serious. The surface roughness of natural grassland is between the two, and the surface vegetation has a certain slowing effect on the wind speed of transit wind, but the effect is not as obvious as that of man-made grassland, and the erosion of soil by wind-sand flow is more serious.

Table 2. Artificial grassland management A surface roughness.

Artificial management of grassland A	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Wind speed in 200 cm (m/s)	4.138	3.585	4.449	4.288	4.699	4.875	3.763	4.582
Wind speed in 50 cm (m/s)	2.893	2.669	3.379	3.262	3.576	3.057	2.720	3.575
Wind velocity contrast	1.430	1.343	1.317	1.315	1.314	1.595	1.383	1.282
Surface roughness (cm)	1.995	0.880	0.628	0.609	0.605	4.860	1.345	0.364
Mean surface roughness (cm)				1.411				

Table 3. Artificial grassland management B surface roughness.

Artificial management of grassland B	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Wind speed in 200 cm (m/s)	4.655	5.062	4.748	5.034	4.055	5.337	4.664	4.158
Wind speed in 50 cm (m/s)	3.512	3.753	3.454	3.622	3.098	4.121	3.382	3.247
Wind velocity contrast	1.325	1.349	1.375	1.390	1.309	1.295	1.379	1.281
Surface roughness (cm)	0.706	0.939	1.236	1.428	0.562	0.456	1.290	0.357
Mean surface roughness (cm)				0.872				

Table 4. Artificial grassland management C surface roughness.

Artificial management of grassland C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Wind speed in 200 cm (m/s)	4.915	5.026	5.326	5.685	6.190	4.544	4.707	5.229
Wind speed in 50 cm (m/s)	3.627	3.674	4.028	4.431	4.667	3.625	3.617	3.996
Wind velocity contrast	1.355	1.368	1.322	1.283	1.326	1.254	1.301	1.309
Surface roughness (cm)	1.008	1.156	0.677	0.373	0.715	0.211	0.502	0.559
Mean surface roughness (cm)				0.650				

Table 5. Artificial grassland management D surface roughness.

Artificial management of grassland C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Wind speed in 200 cm (m/s)	5.135	5.027	4.538	4.729	4.682	5.263	4.526	5.033
Wind speed in 50 cm (m/s)	3.738	3.647	3.252	3.428	3.385	3.949	3.123	3.674
Wind velocity contrast	1.374	1.378	1.395	1.380	1.383	1.333	1.449	1.370
Surface roughness (cm)	1.225	1.282	1.501	1.296	1.342	0.776	2.285	1.178
Mean surface roughness (cm)				1.361				

Table 6. The surface roughness of natural grassland.

Natural grassland	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Wind speed in 200 cm (m/s)	5.574	6.130	5.664	6.061	4.838	5.635	5.463	5.159
Wind speed in 50 cm (m/s)	3.932	4.671	4.215	4.602	3.527	4.328	4.236	3.872
Wind velocity contrast	1.418	1.312	1.344	1.317	1.372	1.302	1.290	1.332
Surface roughness (cm)	1.808	0.591	0.886	0.631	1.200	0.507	0.417	0.772
Mean surface roughness (cm)				0.852				

Table 7. The surface roughness of grazing grassland.

Grazing grassland	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Wind speed in 200 cm (m/s)	6.037	6.410	6.645	5.592	5.823	6.509	6.243	5.740
Wind speed in 50 cm (m/s)	4.587	5.192	5.334	4.647	4.421	5.473	4.780	4.401
Wind velocity contrast	1.316	1.235	1.246	1.203	1.317	1.189	1.306	1.304
Surface roughness (cm)	0.623	0.136	0.178	0.055	0.632	0.033	0.539	0.525
Mean surface roughness (cm)				0.340				

3.3. Characteristics of Sediment Transport in Grassland under Different Management Modes

The vegetation cover in our study area, where is grassland, and desert, was stable and beyond average. Therefore, we used 8 daily average wind speeds and sediment data to measure wind erosion under different management. Finally, we get the grassland sediment discharge data of different management by sorting and further analysis.

3.3.1. Total Sediment Transport in 0-50cm Grassland under Different Management Modes

For 8 days of this experiment, the sediment transport of 0-50 cm layer collected repeatedly in 5 different management modes was set and variance analysis was conducted to obtain the correlation between the sediment transport of grassland under different management modes. Meanwhile, the arithmetic mean of the sediment transport of grassland under different management modes was calculated. The total sediment transport of grassland under different management modes was 0-50 cm layer. The following figure can be obtained by data sorting.

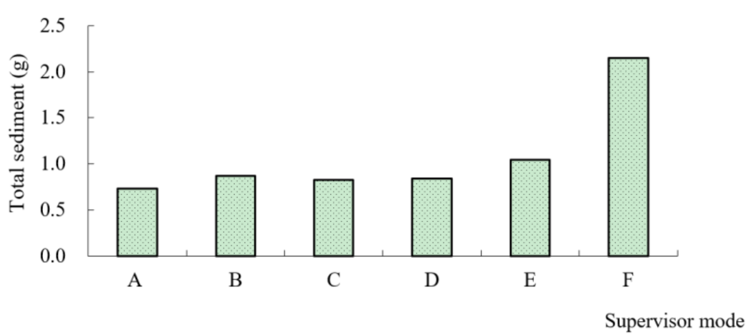

Figure 3. Different management approaches the grass in the 0-50 cm sediment amount change.

As shown in Figure 3, the total sediment transport in 0-50 cm layer of human-managed grassland A, natural grassland and grazing grassland had significant differences ($P < 0.05$) with the total sediment transport in this layer of other five types of grassland under management. The total sediment transport in 0-50 cm layer of artificial management grassland B and artificial management grassland D had no significant difference ($P > 0.05$), but the total sediment transport in 0-50 cm layer of artificial management grassland B and artificial management grassland D had significant difference ($P < 0.05$). However, there was no significant difference in sediment transport between artificial grassland D and B and C in the range of 0-50 cm ($P > 0.05$), but there was significant difference in total sediment transport between artificial grassland D and C in the range of 0-50 cm ($P < 0.05$). The highest sediment transport amount in 0-50 cm layer of grazing grassland was 2.15 g, which was 2.93, 2.48, 2.61, 2.57, 2.05 times of that in human-managed grassland A, human-managed grassland B, human-managed grassland C, human-managed grassland D and natural grassland, respectively. The analysis shows that the artificial tending management can significantly reduce the amount of particulate matter transported in grassland, and the artificial disturbance and destruction increase the degree of wind erosion of grassland soil, which will further lead to grassland degradation.

3.3.2. Changes of Sediment Transport Along Height of Grassland under Different Management Modes

As shown in Figure 4, the variation pattern of the sediment transport of different management modes along the height was basically the same, showing a trend of gradual decrease with the increase of the height from the ground. The variation trend of the sediment transport of grazing grassland was obvious with the change of the height, while the variation pattern of the sediment transport of the other five management modes along the height was not obvious. The reason for this phenomenon is that the grazing grassland has less vegetation on the surface of 0-50 cm, serious soil wind erosion, more particles carried in the process of aeolian sand flow and large sediment transport, so the sediment transport decreases with the increase of height obviously. Compared with the grazing grassland, the vegetation of the grassland under the other five management modes was better, which could effectively reduce the transit wind speed, reduce the particles carried in the movement of the aeolian sand flow, and reduce the sediment transport. Therefore, the variation rule of the sediment transport along the height was not obvious. Compared with human-managed grassland, the sediment transport of natural grassland had a larger variation range with height, and the variation rule of sediment transport along height was not obvious under four human-managed grassland. The fitting equation and correlation coefficient R^2 between sediment transport and ground height were obtained by fitting sediment transport and ground height.

According to the analysis of Table 8, at the significance test level of 0.05, the correlation coefficient R^2 between the sediment transport of grassland under six different management modes and the height from the ground is above 0.95, indicating that the fitting degree between them is very high and can truly reflect the change of sediment transport with the height. The fitting function between the sediment transport and the height from the ground of the artificially managed grassland A was $y=0.228x^{-0.50}$, and the correlation coefficient R^2 value was 0.984. The fitting function between the sediment transport and the height from the ground of the artificially managed grassland B was $y=0.306x^{-0.67}$, and the correlation coefficient R^2 value was 0.987. The fitting function between the sediment transport amount and the height from the ground of the artificially managed grassland C was $y=0.277x^{-0.60}$, and the correlation coefficient R^2 was 0.983. The fitting function between the sediment transport amount and the height from the ground of the artificially managed grassland D was $y=0.257x^{-0.49}$, and the correlation coefficient R^2 was 0.988. The fitting function between the sediment transport of natural grassland and the height from the ground was $y=0.364x^{-0.65}$, and the correlation coefficient R^2 value was 0.991. The fitting function between the sediment transport of human grazing grassland and the height from the ground was $y=0.941x^{-1.0}$, and the correlation coefficient R^2 value was 0.974. The correlation coefficient between the fitting function of D sediment transport and height from the ground was the highest in artificially managed grassland, indicating that the fitting curve of D sediment transport and height from the ground was more authentic than the fitting curve of other managed grassland.

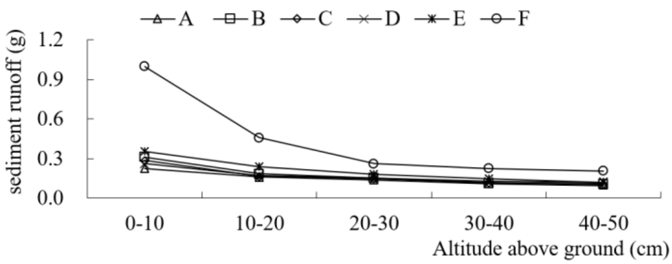

Figure 4. Different management approaches the grass sediment discharge change along the height.

Table 8. Different management approaches the meadow of sediment discharge and the height of the relation.

Supervisor mode	Total sediment discharge	Fitted equation	Correlation index
Artificial management of grassland A	0.735	$y = 0.228x^{-0.50}$	$R^2 = 0.984$
Artificial management of grassland B	0.868	$y = 0.306x^{-0.67}$	$R^2 = 0.987$
Artificial management of grassland C	0.825	$y = 0.277x^{-0.60}$	$R^2 = 0.983$
Artificial management of grassland D	0.838	$y = 0.257x^{-0.49}$	$R^2 = 0.988$
Natural grassland	1.049	$y = 0.364x^{-0.65}$	$R^2 = 0.991$
Grazing grassland	2.151	$y = 0.941x^{-1.02}$	$R^2 = 0.974$

4. Conclusion

(1) The wind speed profiles of grassland under different management methods showed basically the same pattern, which showed that the wind speed increased with the increase of height. The wind speed profiles of grassland UNDER artificial management A and D showed an “S” shaped curve, while the wind speed profiles of grassland under other four management methods showed A “J” shaped curve. The conclusion shows that artificial grass A and artificial management turf D underlying surface conditions than the other four kinds of management mode under the grass surface is more complex, the research results to the vegetation characteristic, because of the artificial grass A and artificial management D grassland vegetation condition is better than the other four kinds of management methods grass, grass artificially management A minimum average wind speed at 20 cm, Compared with other 5 different management methods, the grassland decreased by 31.22%, 40.19%, 15.68%, 45.25% and 53.52%, respectively.

(2) The relationship between grassland wind speed and height from the ground under different management modes is an exponential function. The correlation coefficient R^2

of the fitting equation between grassland wind speed and height from the ground under six different management modes studied in this paper is above 0.95, indicating that the fitting degree of the two is good, and the measured results are highly matched with the fitting equation.

(3) After analyzing the surface roughness of grassland under 6 different management modes, it is concluded that: The surface roughness of human-managed grassland A is the highest, and its average roughness is 61.84%, 117.01%, 3.71%, 65.68%, and 315.03% higher than that of the other five types of grassland. It can be concluded that the surface roughness of human-managed grassland is significantly higher than that of grazing grassland. Artificial herbaceous plants and fencing can improve the surface roughness of grassland and reduce the erosion of surface soil by wind sand flow.

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