WIND FARM EFFECT ON GRASSLAND VEGETATION DUE TO ITS INFLUENCE ON THE RANGE, INTENSITY AND VARIATION OF WIND DIRECTION

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ABSTRACT

Utilizing MOD13Q1-NDVI data from 2000 to 2014, vegetation change in a 50 km buffer area around the Huitengliang wind farm, Inner Mongolia, was analyzed. Combining meteorological data in this analysis, the impact of wind direction on vegetation growth was discussed. Compared with the construction phase (2000-2008), the operation phase (2008-2014) has a more obvious impact on the growth of vegetation. However, the results showed that vegetation impact was uneven: (1) a zone 30-40 km from the center of the wind farm, on the windward side, is likely to be the area of greatest vegetation impact from the wind farm; (2) the proportion of vegetation restoration in the windward/leeward areas, especially in the windward area, is much higher than in the buffer or farm areas; (3) within the wind farm area, the wind farm is not conducive to vegetation growth, while it is helpful to vegetation growth in windward/leeward area.

Index Terms— Wind farm, vegetation change, Huitengliang, grassland

1. INTRODUCTION

In the early stages of establishing wind farms as an energy source, the main focus of researchers and government sectors was energy conservation and emission reduction. As the environmental effects of wind farms occur over long time periods, with gradual changes, they are difficult to measure. Therefore, investigations into the effects of wind farms on the environment are low [1]. As well as the positive environmental effects of wind energy, negative environmental effects of wind power exploitation and operation need to be investigated [2-4]. In this study, the Huitengliang wind farm in Inner Mongolia was used to analyze the impact the wind farm has had on the range, intensity and variation of wind, and the effects to the local grassland vegetation from 2000-2014.

2. STUDIED AREA

The study area was situated at the Huitengliang wind farm, Inner Mongolia (Fig. 1). The wind farm was established in late 2008, ominant vegetation species in the study area are *Leymus chinensis Tzvel, Stipa grandis P. Smirn, Stipa krylovii Roshev* and *Cleistogenes squarrosa Keng.* The outer boundary of the wind farm distribution was determined using a Garmin portable GPS-62SC. The rectangle-area of the wind farm (hereinafter referred to as "wind farm region") was obtained by taking the circumscribed rectangle. Meanwhile, a 50 km buffer zone of the rectangle was obtained（hereinafter referred to as "buffer region"）.

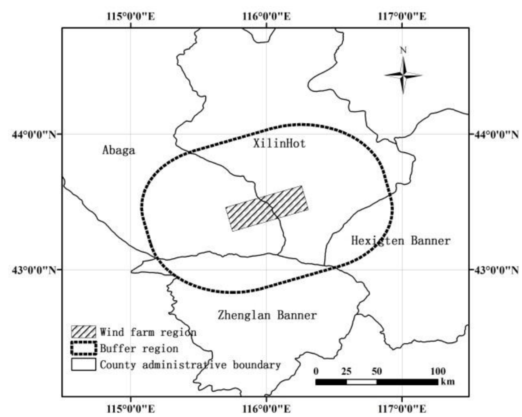

Figure1. Location of the study area

3. DATA SOURCE

(1)Wind direction data from 2000 to 2014 was provided by XilinHot weather stations; (2)MOD13Q1 data from the 113th day to the 305th day of each year between 2000 and 2014 was downloaded from http://ladsweb.nascom.nasa.gov/data/search.html; (3)Land-use map: 1:100,000 land-use maps of 2000 from http://westdc.westgis.ac.cn, 2005 and 2010 classified by the author of this article with the Landsat5-TM data downloaded from http://datamirror.csdb.cn[5].

4. METHODS

4.1 Determination of the meadow distribution area

Aided with the land use maps of 2000, 2005 and 2010, the author worked out the public area of the meadows to within above 3 periods and took the overlap area as the meadow area for the purpose of this research.

4.2 Reconstitution of the NDVI data

HANTS filtering, the author reconstituted the MOD13Q1 -NDVI data with a resolution of 16 days into a NDVI series with a one-year resolution (from 113th day to the 305th day) and used it as the input data [6]. In addition，the seasonally integrated NDVI can effectively reflect the change of surface vegetation [7]. After filtering by adopting HANTS, the NDVI of the period from days 113 to 305 were summarized; these represented the growth conditions of the vegetation in that year (referred to as NDVI_SUM in the following parts).

4.3 Remote Sensing Monitoring of Meadow Change

Linear trend analysis (LTA) was used to monitor the variation condition of vegetation for each year, and to calculate the overall variation condition of NDVI_SUM for each pixel in the two periods respectively, i.e. 2000-2008 and 2008-2014. At the same time, the variation grades of NDVI_SUM were divided[8]. Finally, the percentages of the grades of the buffered area, the rectangle wind power area, the windward area and the leeward area in the grassland area were calculated, these are presented in Table1 (the table was omitted).

4.4 Effect of wind direction on vegetation growth

The wind direction frequency data from 2000 to 2014 was used to create the rose diagram (the figure was omitted). The center of the rectangular study area was taken as the center of a circle. Sectors where then made in the area between the WSW and SSW (the highest frequency of wind direction) which were termed as the "windward region". The "leeward region" was also delimited as the area between the NNE and ENE which had the lowest frequency of wind direction. The radii of the windward and leeward areas were 30 km, 40 km and 50 km. Because the sectors of the 0-30 km radius were in the rectangular region of the wind farm, 0-30 km was taken as the wind farm area to uniformly analyze vegetation.

5. RESULTS AND ANALYSIS

Table 1 (the table was omitted) was created by quantitatively analyzing the vegetation variation condition of each region in Figure 2. Table 1 shows that the vegetation degeneration ratio in the wind farm area from 2000 to 2008 was 3.27%; this was the lowest degeneration ratio in the study. The degeneration ratio of the leeward area during this time period was the highest with 19.68%. The vegetation degeneration ratios of the windward/leeward areas were higher than the wind farm area and the buffer area; this indicated that the degeneration of the windward/leeward area from 2000-2008 was more obvious than in other regions. However, from 2008-2014 the degeneration ratio of each region was similar with the recovery of vegetation; the values fluctuated in the range of 0.97%~2.01% indicating that the recovery of vegetation in the windward/leeward area increased in this time period.

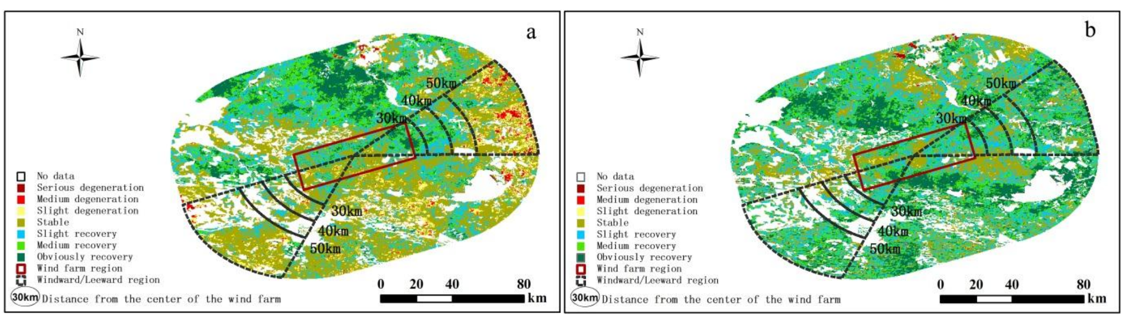

Figure2. The change tendency of vegetation from 2000 to 2008(a)/ from 2008 to 2014(b)

The recovery ratio of the wind farm area in 2000-2008 was 49.98%; this was the greatest recovery ratio for the four areas. From 2008-2014 widespread recovery was recorded for all of the vegetation areas and the vegetation recovery ratio for the wind farm area was up to 63.12%. However, this area recorded the lowest increase of the four areas during this time period. This indicated that vegetation growth was influenced by the operation of the wind farm and that the recovery trend of vegetation slowed due to the wind farm operation. In comparison, the recovery ratio of the buffer area and the wind farm area increased by 26.66% and 13.14%, respectively, from 2000-2008. However, the recovery ratio of the leeward area and the windward area increased by 41.07% and 51.83%, respectively. It can be seen that the vegetation recovery ratios of the windward/leeward areas, especially the windward area, were much higher than other regions.

Using the method highlighted in Section 4.3, the variation of vegetation in the upward and downward areas from the center of the wind farm are presented in Table 2 (the table was omitted). Results show that compared to 2000-2008, the vegetation recovery ratios of the windward area in the ranges of 0-30 km, 30-40 km and 40-50 km in 2008-2014 were significantly greater than those of the leeward area. In addition, (1) the sector area with the radius of 0-30 km was in the wind farm area, thus the interference to vegetation during the construction of the wind farm was similar. The on-site investigation showed that similar grazing land was present in both the windward and leeward areas in this range, therefore the interference of herbivores was also similar. However, vegetation recovery for the windward area was nearly four times larger than that for the leeward area, thus the effect of the wind farm on the vegetation in the windward area was more obvious when compared to the leeward area. (2) In the range of 30-40 km, vegetation recovery in the windward area was more than 20 times greater than the leeward area, although the ratio of recovery decreased when the distance was between 40-50 km, or more than 50 km. Our results indicate that the windward region 30-40km from the center of wind farm was the most affected area. Our results differ from those from other ecological investigations on the microscale [4].

In general, Tables 1 & 2 show that the vegetation of the buffer area, the wind farm area and the windward/leeward areas were in a state of recovery when compared to the state of vegetation before the establishment of the wind farm. Compared to the buffer area, the ratio of recovered vegetation of the wind farm area decreased, however, the recovery of vegetation in the windward/leeward area had accelerated, especially for the windward area.

6. DISCUSSION AND CONCLUSION

6.1 Discussion

The following factors provide uncertainty to our research results: (1) differences in the range of the buffer area can affect the vegetation growth ratio. Examining the different ranges of the buffer area surface on a regional scale was a complicated process, however it was an important analysis to investigate whether grazing intensity was strictly consistent; and (2) different scales of wind farm had different impacts on the intensity and range of different underlying surface vegetation. In addition, the conclusions of this study reflect features of local vegetation and climate to the Huitengliang wind farm. Temperature and rainfall were two significant factors in determining the growth of vegetation. The mean annual temperature and annual precipitation showed an increasing tendency, and the vegetation growth in this region was positively correlated with temperature and rainfall [9]. The influence of the wind farm on the regional rainfall was limited [1], thus the recovery of vegetation in the windward/leeward area was probably caused by the accelerated rise in temperature. In a region with insufficient or decreasing rainfall, the establishment of a large-scale wind farm may lead to the formation or acceleration of regional climatic drought. The effect of these factors on vegetation growth processes was complicated and the variation of each influencing factor was not analyzed and verified in this study.

6.2 Conclusion

The installation and operation of the Huitengliang wind farm has had obvious effects on the local vegetation in the rectangular power plant area and within 50 km of the buffer area. However, the range, intensity and direction of influence differed. It mainly presented as:

(1) a zone 30-40 km from the center of the wind farm, on the windward side, is likely to be the area of greatest vegetation impact from the wind farm; (2) compared with the wind farm construction stage, the proportion of vegetation restoration in the buffer area and the farm area during the operational phase of the wind farm increased by 26.66 % and 13.14 %, respectively. The proportion of vegetation restoration in the leeward and windward areas, however, increased by 41.07 % and 51.83 %, respectively, over the same time period. This indicates that the proportion of vegetation restoration in the windward/leeward areas, especially in the windward area, is much higher than in the buffer or farm areas; (3) the influencing mechanisms of a wind farm on vegetation differ within and outside of the farm area. Within the wind farm area, the wind farm is not conducive to vegetation growth, while it is helpful to vegetation growth in windward/leeward area.

ACKNOWLEDGEMENT

This research received financial support from the National Natural Science Fund of China (grant number: 31570451, 41271342) and the National Basic Research Program of China (973 Program: 2014CB138803).

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