Research on the protection of wind and sand erosion in Saihanba Forest Farm based on ecological environment assessment model

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Abstract. The establishment of the Saihanba forest has played a very important role in preventing wind and sand and maintaining the ecology. Mathematical modeling methods including meta-automata simulation algorithm, OLS regression analysis, and quadratic coherence method were used to investigate the impacts of the Saihanba forest. After the establishment of the Saihanba Tree Farm, its ability to prevent wind and sand and maintain ecological balance was greatly improved, and the environmental conditions were greatly improved. In addition, we simulated the wind and sand attack on Beijing using a meta-automaton simulation, and specifically analyzed the wind and sand impact on five height classes of buildings. The results showed that the establishment of the Saihanba forest farm had a significant effect on improving the ability of Beijing to withstand sandstorms.

Keywords: Saihanba Forest Farm, meta-automata simulation algorithm, OLS regression analysis, quadratic coherence method, wind and sand erosion.

1. Introduction

Since the beginning of the 21st century, the process of industrialization has accelerated and the total amount of carbon emissions has been increasing, posing threats and challenges to the ecological environment increasingly. In 1962 Saihanba Forest Farm began to be established and up to now, the area of existing forest is up to 1.151 million mu. Saihanba Forest Farm has not only made great contributions to carbon neutrality, but also constructed a solid green ecological barrier. In the present paper, Mathematical modeling methods were used to investigate the impacts of the Saihanba forest.

2. The main models used in this paper

A comprehensive index evaluation system was constructed through the main hierarchical analysis and entropy weight method. The meta-cellular automata simulation and simulation algorithm, OLS regression analysis model and quadratic coherence method were used for the following analysis in depth. All data analysis and graphing were conducted by MATLAB (2020b, U.S.).

3. Results

3.1. The establishment and analysis of ecological environment evaluation model

Since the main factor affecting sandstorm and sand erosion is wind field intensity, we firstly collected data about wind field intensity in the region and realize a 3D simulation of wind field at different heights to reflect the wind and sand resistance of the region (Figure 1a). After that, we divided the wind field strength into three directions: u, v, and w. We drew the three-way function image of wind field strength by fitting the data to the original wind field strength image and compared it with the original wind field strength image (Figure 1b).

In addition to the intensity of the wind field, we also studied and analyzed the frequency of the wind field in the area, and plotted the frequency images of the wind field for different wind components at different test times (Figure 2).

We fitted the wind field frequency function images for different wind components at different times and heights by means of regression analysis (Figure 3a), after which we integrated the wind field intensity as well as frequency and compared the data groups with the fitted regression curves by means of OLS regression analysis, and the specific image is as Figure 3b follows.

Based on the above fitted regression analysis images, we can find that the wind field in the u-direction has the greatest influence on the degree of wind and sand erosion in terms of both wind field intensity and wind field frequency, and the u-direction is roughly due north geographically, which is consistent with the direction of the winter wind. After that, we further analyzed the wind field in the area by quadratic coherence (Figure 4a) and the data were analyzed again to obtain the fitted regression analysis images (Figure 4b).

Finally, we considered the wind field factor jointly with the sanding factor and simulated it by matlab to draw a specific schematic diagram of wind and sand resistance in the Saihanba area during a certain period of time in November 2021 (Figure 5).

Through the above analysis, we can find that after the implementation of the mechanical forest planting project in Saihanba Forestry Park, compared with the previous one, its ability to prevent wind, fight sand and maintain ecological balance has been greatly improved, and the environmental conditions have been greatly improved.

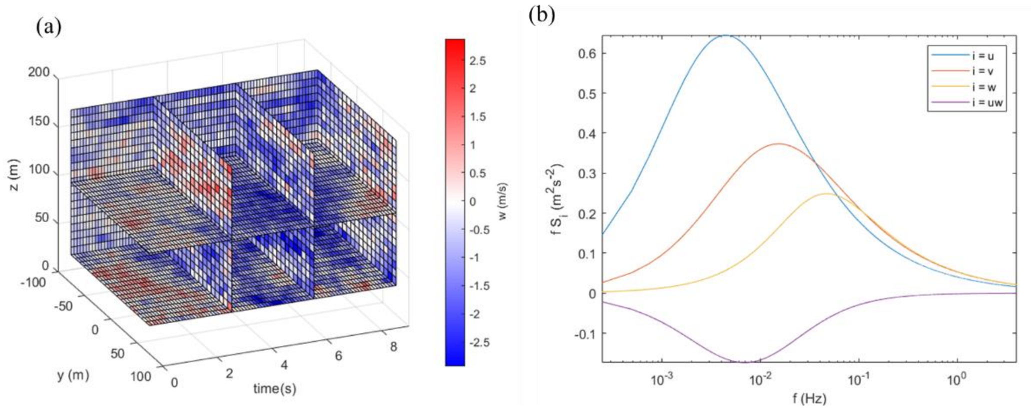

Figure1. 3D wind field intensity simulation (a) and wind direction function (b).

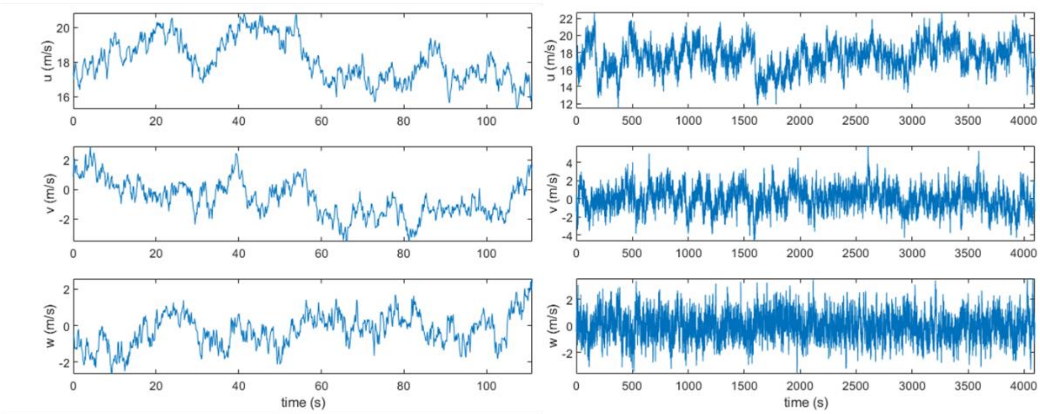

Figure 2. Wind frequency

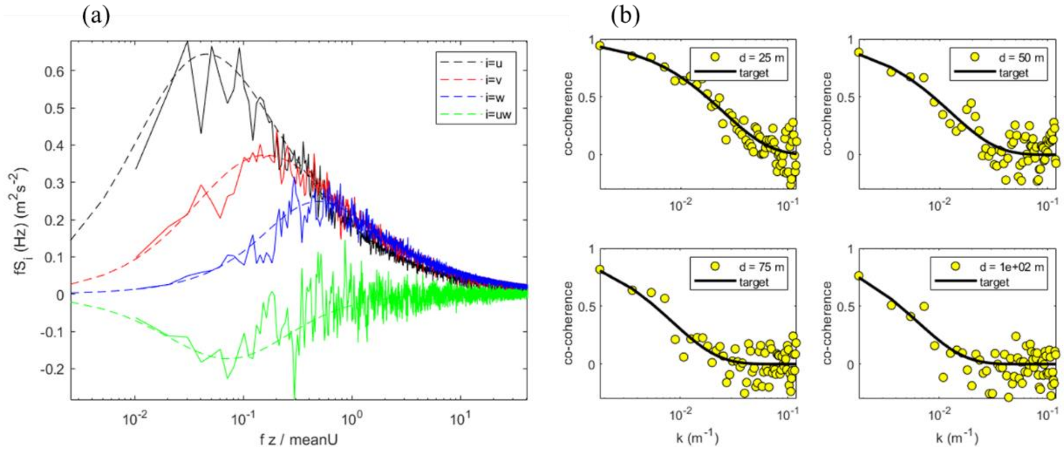

Figure 3. Wind field frequency function (a) and Wind field data regression fitting (b)

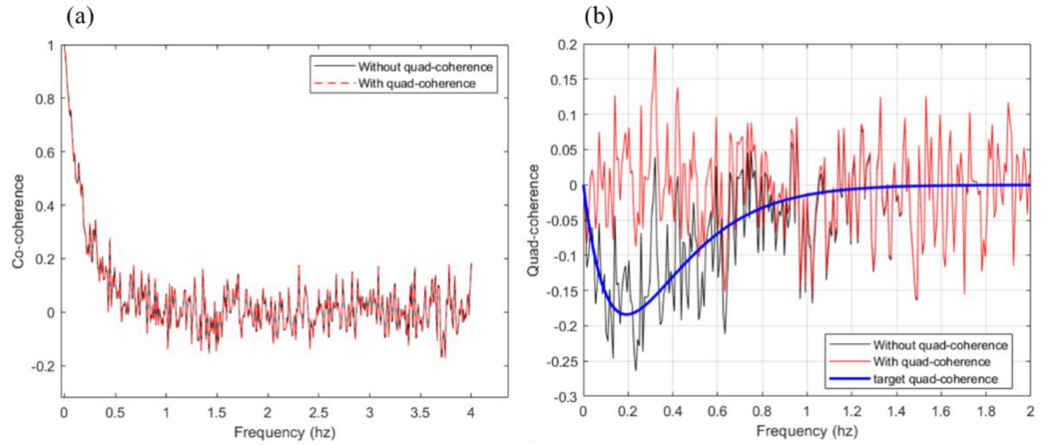

Figure 4. Quaternary coherence image of wind field (a) and its regression fitting image (b)

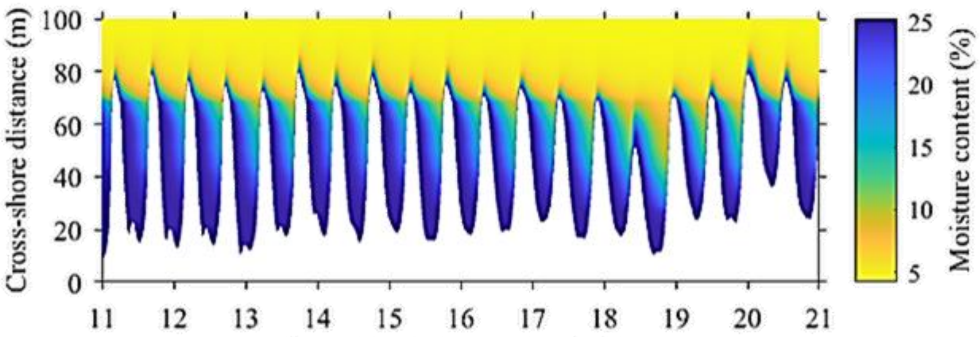

Figure 5. Sandstorm intensity simulation image of Beijing in November

3.2. The effect on improving Beijing's ability to withstand sandstorms

From the results of 3.1, we can know that the u-direction (the northwest direction) has the greatest degree of wind and sand erosion, so we simulate the wind and sand erosion in Beijing through the meta-cellular automaton algorithm, and the specific images are as shown in Figure 6.

Since the urban buildings in Beijing vary, we divided the buildings in the whole Beijing area into five classes based on height, and also idealized some irregular and special buildings with special materials and properties, and fitted the data to the degree of wind and sand impact they suffered after the establishment of the Saihanba Ecological Reserve, and obtained the following results (Figure 7).

From the above figure, it can be seen that with the increase of the height of the floor, the wind strength exposed to in its geographical location was increased, subsequently the degree of wind and sand impact it receives. It is obvious from the results that the degree of wind and sand impact on buildings is inversely related to its distance from the sand source. Therefore, after the establishment of the Saihanba reserve, the degree of wind and sand impact from long distances in the northwest direction becomes less in the Beijing area.

We collected data on the extent of wind and sand erosion impact in a section of Beijing before and after the establishment of the Saihanba Reserve, and simulated and compared them by means of a meta-automata model with the following comparative images (Figure 8). From this we can conclude that the establishment of the Saihanba Forestry Park has a significant effect on improving Beijing's ability to withstand sandstorms.

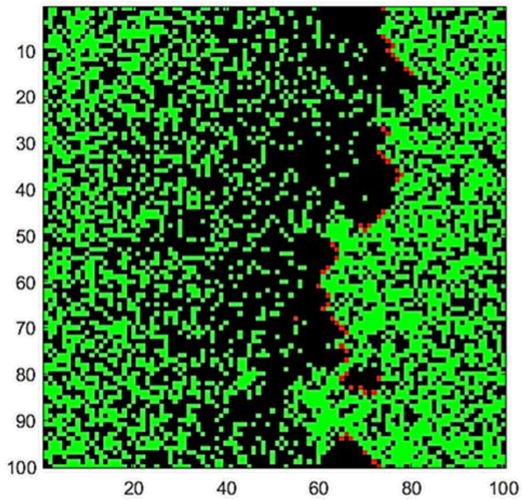

Figure 6. Sand erosion cell image. The black blocked area is the Saihanba Reserve, and the area on the right is the Beijing area

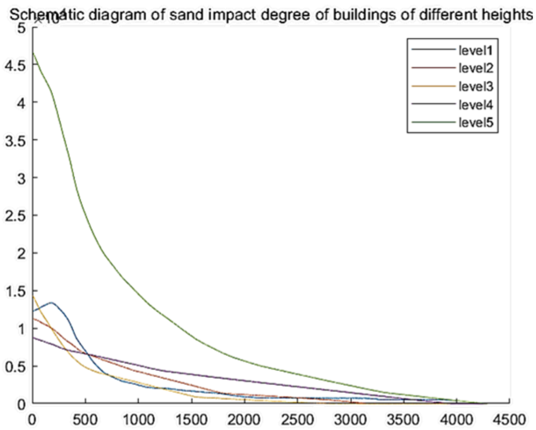

Figure 7. High level sand impact degree

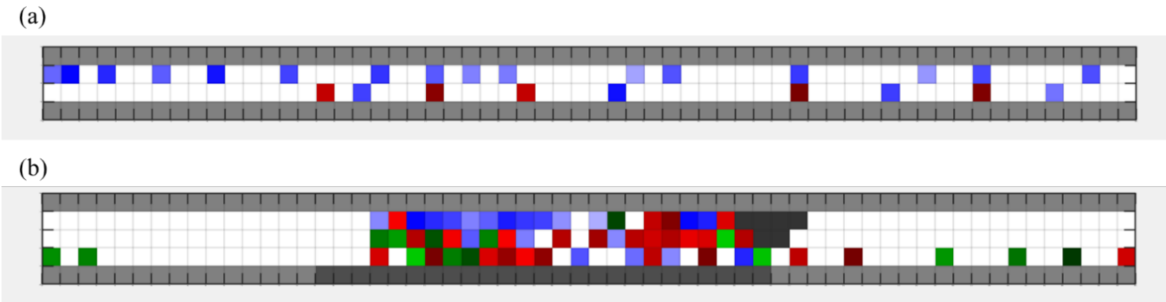

Figure 8. Schematic diagram of wind and sand erosion before (a) Saihanba is established and after establishment (b)

4. Conclusions

A series of models were established in order to evaluate the environmental improvement after the establishment of Saihanba Forest Farm and the protective effect on sand erosion in Beijing. The results showed that after the establishment, its ability to prevent wind and sand and maintain ecological balance was greatly improved, and the environmental conditions were greatly improved, and had a significant effect on improving the ability of Beijing to withstand sandstorms.

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