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A study on the prediction of dandelion spread based on simulation analysis

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Abstract. In this paper, a dispersal prediction model was established to predict the dispersal of dandelion by taking dandelion as the research object and analyzing the climatic conditions of the key parameters of dandelion seeds. Firstly, the key parameters of dandelion seeds were introduced, including the number of crown hairs, the average length of crown hairs, and the diameter of crown hairs. Then a dispersal prediction model was established to predict the dispersal of dandelion in different regions by simulating the seed dispersal process and the influence of climatic conditions. The model is based on the movement characteristics of dandelion seeds in the air and the influence of climatic conditions on seed dispersal, and combines the methods of mathematical modeling and experimental data analysis to provide a comprehensive study and prediction of dandelion dispersal.

Keywords: Dandelion; Propagation Prediction; Climate Impact; Simulation Analysis; Wind Speed Distribution.

1. Introduction

Dandelion is a widely distributed plant, and its seed dispersal mode is of great significance to the ecological adaptation and population distribution of the plant. As an endemic species in alpine regions, the seed dispersal of the snow dandelion has an important impact on the stability of ecosystems and the succession of plant communities. However, the seed dispersal pattern of Taraxacum chionophilum dahlst and its adaptation in different climatic environments remain many unanswered questions due to the influence of climatic conditions [1].

Against this background, this study aims to investigate the effects of different climatic conditions on the growth and dispersal of dandelion, as well as the adaptation of dandelion to climate change, through in-depth studies on key parameters and dispersal models of snowy dandelion. By comprehensively analyzing the bio morphological characteristics of dandelion seeds, parameters of environmental conditions, and the effects of climatic factors on seed dispersal, we aim to reveal the mechanism of dandelion populations in ecosystems, and provide important references to understand the distribution patterns of plant populations and the dynamic changes of ecosystems [2].

Therefore, this paper will firstly introduce the biological characteristics and distribution of snowy dandelion, then put forward the purpose and significance of the study, and finally lead to the key questions and research methodology of this study, with a view to exploring in depth the ecological significance and mechanism of seed dispersal of dandelion [3].

2. Spread Prediction Model

2.1. Key Parameters of Taraxacum Chionophilum Dahlst

In this paper, the taraxacum chionophilum dahlst was used in the research object. The taraxacum chionophilum dahlst is a species of dandelion in the Asteraceae family, which is distributed in northwest Sichuan Province in China. This kind of “special” dandelion is the sample that we research on. We only focus on one kind of dandelion and the“chionophilum dahlst”[4]. The key parameters of partial biomorphology of taraxacum chionophilum dahlst seeds in the paper is shown in Table 1:

Table 1. Key Parameter of Dandelion Seeds

Sequence Number	Parameter	Result
1	Pappus number	25-35/root
2	Average pappus length	12/mm
3	Pappus diameter	0.18-0.20/mm
4	Equivalent disk diameter	40/mm
5	Dandelion height	10/cm

To better calculate and predict the future situation of dandelions, we collected some experimental data. According to these data, the relevant parameters are obtained. Related parameters are as follows:

The air density is $\rho = 1.204\ \mathrm{kg/m^3}$

The air viscosity is $v = \frac{\mu}{\rho} = 1.516 \times 10^{-5}\ \mathrm{m^2/s}$

The temperature is 293.15 Kelvin, and the pressure is 101.325 kPa.

We unanimously believe that under these conditional data, the calculated results are the most efficient and closest to the actual situation. This is also the reason why we chose these experimental data.

With this data, we can combine land area and land shape. Perform data modeling and then predict the seed dispersal of a dandelion plant "next to the field."

2.2. Model Establishment

2.2.1. Initialization of Parameters.

In the spread prediction model, suppose that the shape of a hectare of land is a circle, the center of the circle is the origin of the coordinate system, and there is a dandelion in the "floating ball" stage on the arc of the circular land. The size of the target land is 1 hectare (10,000 square meters), that is, a piece of land measuring 100 meters by 100 meters. Each square meter of land is defined as follows:

(x,y) indicates the location of the land, where the x value indicates that the land is in column x, and the y value indicates that the land is in row y. n_d represents the number of dandelions on this square meter, and n_s represents the number of seeds that fell on this square meter.

2.2.2. Seeds Dispersal.

Because dandelion seeds are transmitted by wind, the probability distribution function of the local wind speed is defined as:

$$f(v_0; \lambda, k) = \frac{k}{\lambda}\left(\frac{v_0}{\lambda}\right)^{k-1} e^{-\left(\frac{v_0}{\lambda}\right)^k} \tag{1}$$

$PDF(v_0; \lambda, k)$ is the cumulative probability function of the local wind speed, representing the probability that the wind speed v is less than the ultimate wind speed v0. In this Weibull distribution function, λ is the scale parameter, k is the shape parameter, and v0 is the limit of wind speed. The cumulative distribution function of the local wind speed is defined as:

$$F(v_0; \lambda, k) = 1 - e^{-\left(\frac{v_0}{\lambda}\right)^k} \tag{2}$$

As shown in figure 1, we assume that the area of the crown hairs at the top of the dandelion seed is a complete circular geometry, and the thickness is ignored [5-6].

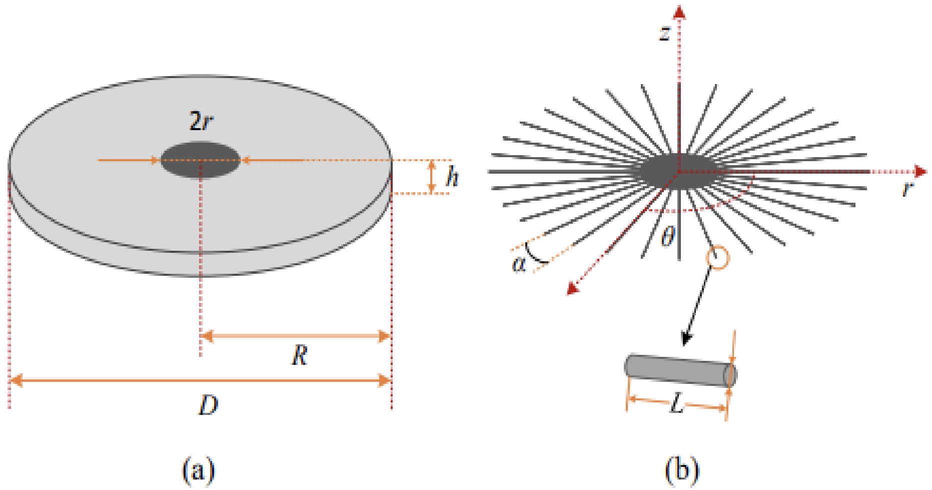


Figure 1. The geometric model of dandelion seed

A cylindrical coordinate system is defined, whose origin coincides with the center of the porous disk, and its Z direction is parallel to the inflow velocity. The model has the biological morphological parameters of dandelion, as shown in Table 2.

Table 2. Dandelion basic information

Sequence number	Parameter	Meaning	Result
1	n	Pappus number	30/root
2	L	Pappus length	12/mm
3	r	The radius of the central solid disk	2/mm
4	d	Pappus diameter	0.19/mm
5	h	Geometric model thickness	0.19/mm
6	D	Model diameter	40/mm
7	C	Drag coefficient	6.38

Define the ratio of the projected area of the disk pores to the total disk area, which is expressed as:

$$\kappa = 1 - \frac{nd\left(\frac{D}{2}-r\right)+\pi r^2}{\pi\left(\frac{D}{2}\right)^2} \tag{3}$$

Where, n is the number of pappi, d is the diameter of the pappus, D is the diameter of the model, and r is the radius of the central solid disk [11].

Therefore, the air resistance of a single dandelion seed in the air is

$$F = \frac{1}{2} C \cdot \rho \cdot S \cdot v_r^2 \tag{4}$$

Then, the horizontal force of the seed in the air is

$$F_{net} = F = \frac{1}{2} C \cdot \rho \cdot S \cdot v_r^2 = m \cdot a \tag{5}$$

Therefore,

$$\frac{1}{2} C \cdot \rho \cdot S \cdot (v - v_d) = \frac{dv_d}{dt} \cdot m \tag{6}$$

After that, we can get that

$$v_d = v - \frac{1}{\frac{1}{2m} \cdot C \cdot \rho \cdot S \cdot t + \frac{1}{v}} \tag{7}$$

According to the obtained dandelion seed velocity V0, we can get the dandelion propagation distance D under the action of wind is

$$D = v_d \cdot t \tag{8}$$

Then substitute equation (7) into equation (8):

$$D = v - \frac{1}{\frac{1}{2m} \cdot C \cdot \rho \cdot S \cdot t + \frac{1}{v}} \tag{9}$$

This image represents a simplified model of the propagation of a dandelion. The propagation of a dandelion is a horizontal parabolic motion, which is accelerated by the horizontal wind force on the way down. The drop height is the distance between two points a and b, and the propagation distance is expressed as the distance between two points a and c [7].

2.2.3. Climate Impact.

In this part, the discussion is around the influences on the growth and spread of dandelion under different climatic conditions. Climate conditions will be set in tropical, temperate and cold zones to explore the effects of temperature, humidity and light on dandelion growth caused by different latitude conditions. After flowering has ceased, dandelion capitula close to enable maturation of seeds, and the seed maturity period is 9 days. Ripening seeds of maturing capitula only remained germinable if desiccation temperatures were ≤ 35°C (optimum 25°C) and will be died at 45 and 55°C.

2.3. Simulation Analysis

2.3.1. Wind Distribution Analysis.

Using the Python Crawler, we calculated and analyzed the distribution of wind speed in recent decades by obtaining wind speed data (expressed in latitude and longitude) for different regions on the NASA website [8]. Through the fitting analysis of all wind data from January 1, 2000 to January 1, 2023, it is found that the wind distribution conforms to Weibull distribution, and the shape parameters, scale parameters and location parameters of Weibull distribution are obtained. Take the Tibetan Plateau as an example, the graph below represents the cumulative distribution function of the wind and the probability density function conforming to the Weibull distribution, as shown in figure 2.

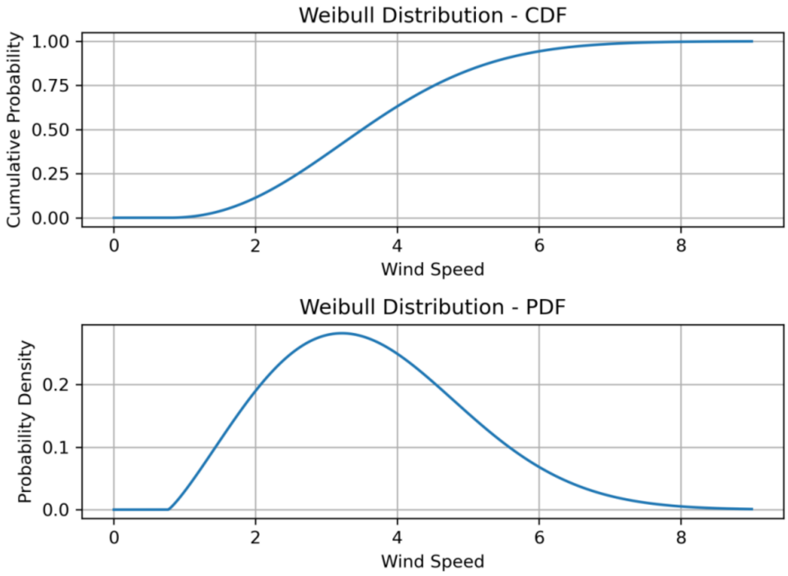


Figure 2. Weibull distribution -PDF/CDF

By fitting the Weibull distribution of wind speed, the resulting parameters are used to randomly generate wind speed conforming to this Weibull distribution, which is used to calculate the effect of the wind force received by dandelions [9-10].

The randomly generated wind speed used for the simulation conforms to the Weibull distribution of the metadata wind speed.

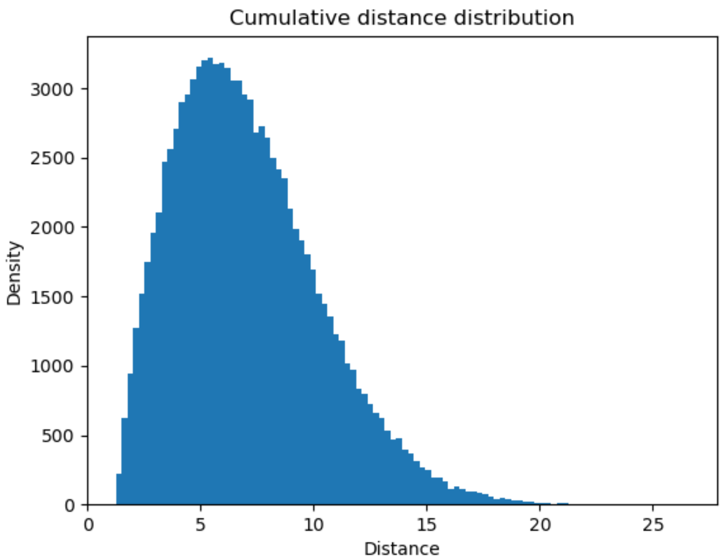


Figure 3. Cumulative distance distribution

It can be seen from Fig.3 that the distance distribution calculated by the model also accords with Weibull distribution.

$$\theta = 2\pi \times {}_{\text{rand}}(0,1) \tag{10}$$

This function is a randomly generated wind speed, where rand (0, 1) represents a function that generates a random number between 0 and 1.

2.3.2. The Influence of Climatic Conditions.

Seeds go through several stages: germination, flowering and fruiting. Our group obtained some data through search and used this data for data programming and prediction. The number of days in these phases is mainly affected by climate, including temperature, light intensity, and precipitation. Under the influence of these three factors, the time of the three stages will change to a certain extent. The approximate duration of these three phases is:

Seeds will germinate within 10 to 15 days, bloom within 30 to 60 days after germinating, and fruit within 13 to 15 days after flowering.

Temperature:

When the temperature is 0 to 15 degrees Celsius (a random number between them), dandelion seeds take 13 to 15 days (a random number between them) to germinate, 40 to 60 days (a random number between them) to bloom, and 14 to 15 days after flowering (a random number between them) to fruiting.

When the temperature is 15 to 25 degrees Celsius (a random number between them), dandelion seeds take 10 to 12 days (a random number between them) to germinate, 30 to 45 days (a random number between them) to bloom, and 13 to 14 days after flowering (a random number between them) to fruiting.

When the temperature is 25 to 30 degrees Celsius (a random number between them), dandelion seeds take 13 to 15 days (a random number between them) to germinate, 45 to 60 days (a random number between them) to bloom, and 14 to 15 days after flowering (a random number between them) to fruiting.

Based on the above data, dandelion seeds progress through these three stages the fastest when the temperature is between 15 and 25 degrees Celsius. Therefore, the best temperature for dandelions is 15-25 degrees.

Light intensity:

When the light intensity is smaller than 11810KJ (a random number between them), dandelion seeds take 13 to 15 days (a random number between them) to germinate, 40 to 60 days (a random number between them) to bloom, and 14 to 15 days after flowering (a random number between them) to fruiting.

When the light intensity is 11810KJ to 14173KJ (a random number between them), dandelion seeds take 10 to 12 days (a random number between them) to germinate, 30 to 45 days (a random number between them) to bloom, and 13 to 14 days after flowering (a random number between them) to fruiting.

When the light intensity is greater than 14173KJ (a random number between them), dandelion seeds take 13 to 15 days (a random number between them) to germinate, 30 to 45 days (a random number between them) to bloom, and 14 to 15 days after flowering (a random number between them) to fruiting.

Based on the above data, dandelion seeds progress through these three stages the fastest when the light intensity is between 11810Kj and 14173KJ. Therefore, we can deduce the most suitable light intensity is in this range.

Precipitation (per year):

When the precipitation is 90 to 500mm (a random number between them), dandelion seeds take 13 to 15 days (a random number between them) to germinate, 40 to 60 days (a random number between them) to bloom, and 14 to 15 days after flowering (a random number between them) to fruiting.

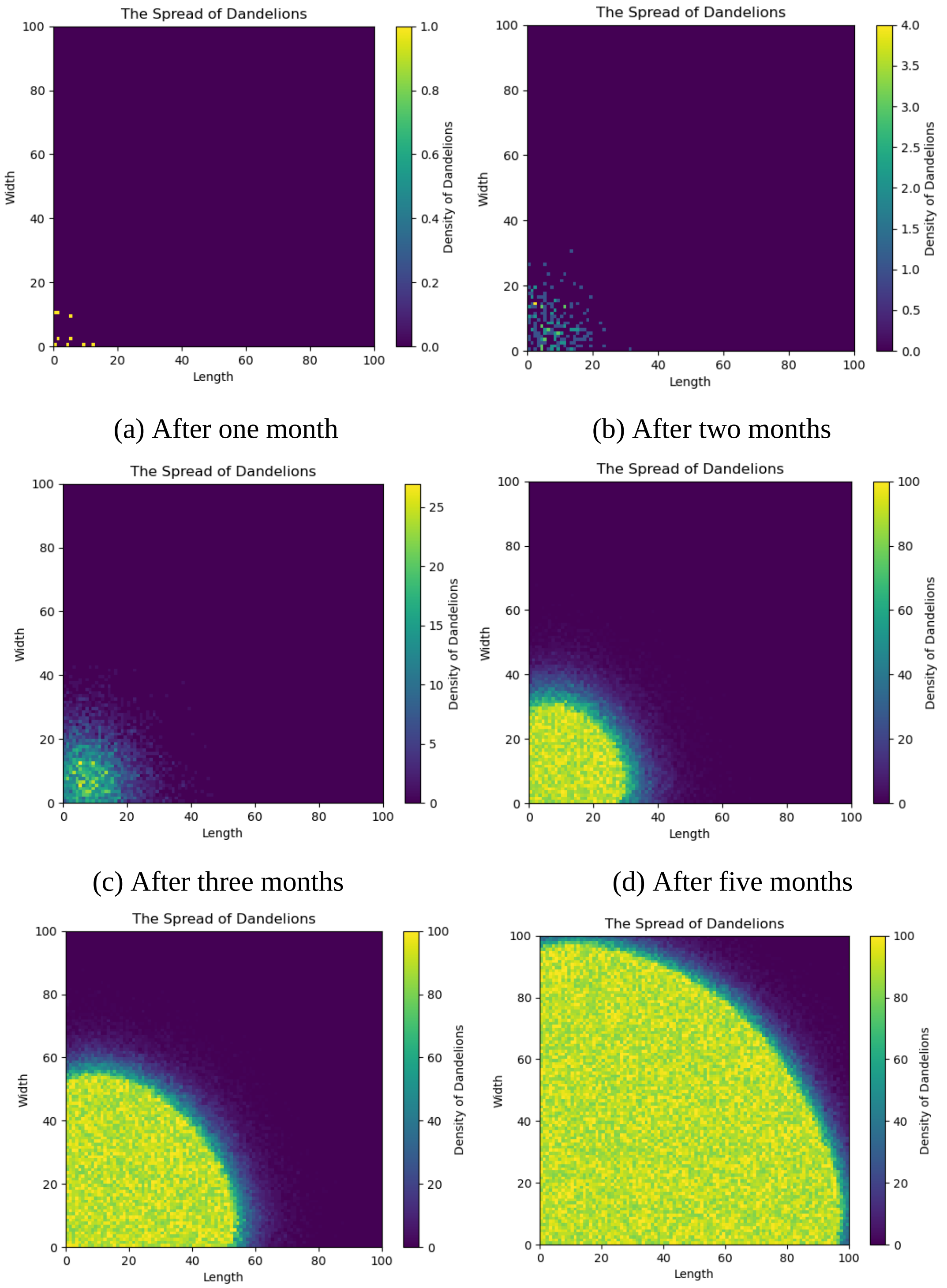
When the precipitation is 500 to 1000mm (a random number between them), dandelion seeds take 10 to 12 days (a random number between them) to germinate, 30 to 45 days (a random number between them) to bloom, and 13 to 14 days after flowering (a random number between them) to fruiting.

When the precipitation is 1000 to 2780 mm (a random number between them), dandelion seeds take 13 to 15 days (a random number between them) to germinate, 30 to 45 days (a random number between them) to bloom, and 13 to 14 days after flowering (a random number between them) to fruiting.

Based on the above data, dandelion seeds progress through these three stages the fastest when the precipitation is between 500 to 1000 mm. Thus, we can deduce the most suitable precipitation is in this range

2.3.3. Data Analysis.

According to the Spread Prediction Model, we simulate the spread of dandelion. The figure below shows the spread of dandelion in one year on the Tibetan Plateau.



(a) After one month (b) After two months

(c) After three months (d) After five months

(e) After six months (f) After twelve months

Figure 4. The spread of dandelions

As shown in the figure 4, at the time of the first month, the spread of the dandelions was small, with all the dandelions within 10m of the original dandelions. After two months, dandelions can spread around 20 meters. From February to May, the dandelions continue to spread out in circle. After May, the rate of dandelion spread greatly increases, on account of the base number of dandelions increases. By December, dandelions can be found covering most of a hectare of land without the influence of other species.

2.3.4. Impact Analysis of Climatic Conditions.

To explore the impact of different climatic conditions on the spread of dandelion, we changed the proposed area (Turpan Basin). The biggest difference between this area and the Tibetan Plateau is the wind speed (smaller) and drought.

By fitting the wind speed data in the Turpan Basin (from January 1, 2000 to January 1, 2023), we can find that the probability density distribution (PDF) and cumulative density function (CDF) of the wind speed in the Turpan Basin are higher than those in the Tibetan Plateau. There is a significant difference between them, as shown in figure 5.

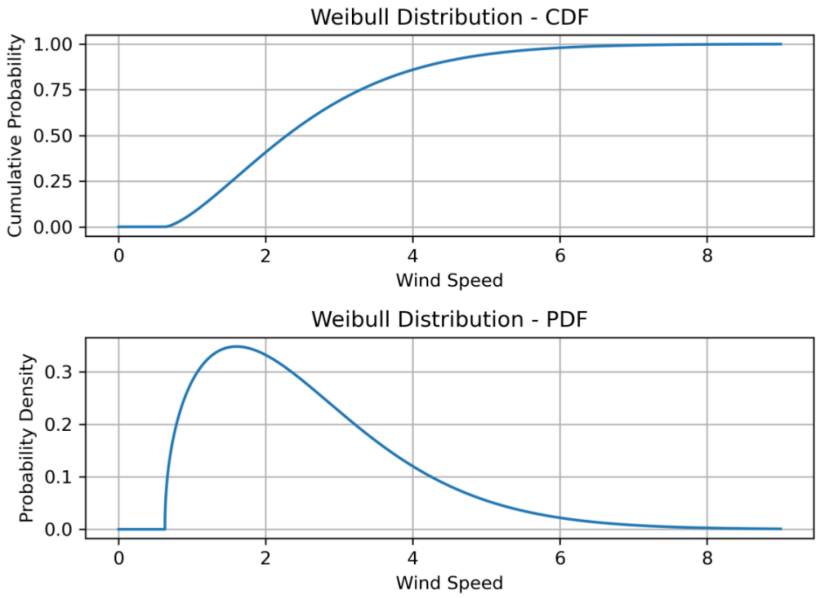


Figure 5. Weibull distribution CDF/PDF

3. Conclusion

This paper focuses on the key parameters and dispersal models of snowy dandelion and the effects of different climatic conditions on the growth and dispersal of dandelion. Firstly, the key bio morphological characteristics of dandelion seeds and parameters of environmental conditions, including air density, air viscosity, temperature and pressure, were obtained from experimental data. Then, a seed dispersal model was established to predict the dispersal distance and speed of dandelion under different climatic conditions, considering the effects of land shape and wind on seed dispersal. Then, the effects of climatic factors such as temperature, light intensity and precipitation on the growth stages of dandelions were analyzed, providing an in-depth understanding of dandelion dispersal and growth mechanisms. Finally, through simulation and data analysis, the dispersal patterns of dandelions in different regions and their adaptation to climate change were explored, providing an important reference for understanding the dandelion ecosystem and ecological balance.

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