Scientific Research Publishing

American Journal of Plant Sciences, 2024, 15, 252-267
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Modeling Analysis of Factors Influencing Wind-Borne Seed Dispersal: A Case Study on Dandelion

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How to cite this paper: Xue, K.M. (2024) Modeling Analysis of Factors Influencing Wind-Borne Seed Dispersal: A Case Study on Dandelion. *American Journal of Plant Sciences*, **15**, 252-267.
https://doi.org/10.4236/ajps.2024.154018

Received: January 22, 2024
Accepted: April 26, 2024
Published: April 29, 2024

Abstract

A weed is a plant that thrives in areas of human disturbance, such as gardens, fields, pastures, waysides, and waste places where it is not intentionally cultivated. Dispersal affects community dynamics and vegetation response to global change. The process of seed disposal is influenced by wind, which plays a crucial role in determining the distance and probability of seed dispersal. Existing models of seed dispersal consider wind direction but fail to incorporate wind intensity. In this paper, a novel seed disposal model was proposed in this paper, incorporating wind intensity based on relevant references. According to various climatic conditions, including temperate, arid, and tropical regions, three specific regions were selected to establish a wind dispersal model that accurately reflects the density function distribution of dispersal distance. Additionally, dandelions growth is influenced by a multitude of factors, encompassing temperature, humidity, climate, and various environmental variables that necessitate meticulous consideration. Based on Factor Analysis model, which completely considers temperature, precipitation, solar radiation, wind, and land carrying capacity, a conclusion is presented, indicating that the growth of seeds is primarily influenced by plant attributes and climate conditions, with the former exerting a relatively stronger impact. Subsequently, the remaining two plants were chosen based on seed weight, yielding consistent conclusion.

Keywords

Seed Dispersal, Wind Intensity, Climatic Effect, Factor Analysis Model

1. Introduction

1.1. Background

Seeds play a crucial role in the process of plant reproduction, serving as a vital link. Within the plant community, approximately 10% - 30%, and even up to 70% of temperate plants possess wings or hairs on their seeds or fruits, facilitating dispersal through wind. The wind-mediated dispersion of plant seeds is pivotal for population renewal and migration [1]. Scholars have conducted research on the process of wind disposal of seeds, including observing the wind disposal characteristics of different plant seeds [2] [3], analyzing the disposal distance and wind direction [4], etc. Chen Lingling [5] proposed a new spatial disposal model-quasi-Maxwell spatial distribution model, which is used to describe the disposal behavior of herbaceous seeds in long, medium and short distances, and has realized the simulation of seed disposal in any direction and area under windless or windy conditions. The model also conducts adaptive analysis by utilizing previously available experimental or measured data. However, this model has some shortcomings, such as only qualitative description of wind force, and can only distinguish between wind and wind direction, lack of quantitative description of wind force. In this paper, based on the quasi-Maxwell spatial distribution model established by Chen Lingling [5], wind intensity was introduced into the model, wind intensity grade was incorporated into the seed disposal model as a parameter, and the model was modified. Then, taking Beijing, Hainan and Jiayuguan in China as typical representatives of temperate, tropical and arid regions respectively, the wind-borne seed model was applied to different regions to simulate the probability distribution curve of wind-borne seed distance. Dandelion is a typical seed wind propagating plant. There is no study on the effect of wind grade on seed wind propagating distance of these plants under different climatic conditions. Factors such as temperature, humidity and solar radiation were further considered, and factor analysis model was used to analyze the factors affecting seed growth and disposal and their influence rules.

The seeds of dandelion have a small weight of 1000 seeds, which are typical wind-borne plants, which are distributed all over the world, and have certain ornamental and medicinal value, and the study of the seed dispersal characteristics of dandelion has a good demonstration significance for the promotion of crops and the excavation of economic value, and has certain significance for preventing the invasion of harmful plants like dandelion. Therefore, in this study, dandelion was selected as an example, and the parameters of the model were set according to the seed weight and production cycle of dandelion.

1.2. Assumptions and Symbols

For the limitation of available data and the convenience of calculation, the model assumes the following content:

Assumption 1: Dandelion is growing in the center of the land, which has a round structure.

Assumption 2: Dandelion must be the same species. The same species of dandelion must be considered as the fixed variable. Different kinds of dandelion are not a variable included in the experiment and equations.

Assumption 3: The wind direction is not considered as a variable in the dispersal function, and we only consider the wind strength as a variable.

2. Dandelion Wind Disposal Model

2.1. Impact of Wind Intensity on Seed Disposal Distance

2.1.1. Revised Wind Dispersal Model

To increase the complexity and precision of the model, we construct and add another part of model to justify the solution. The following information could help us to verify the results.

From bibliographic retrieval, we have quoted Lingling Chen's model [5] about the seed dispersal.

$$F(r,\theta)=\frac{\left(1+\cos\left(\theta-\theta_0\right)\right)\alpha^2\left(\mu\delta\right)^{(2+\alpha)/\alpha}}{4\pi\Gamma\left(2/\alpha\right)}\mathrm{r}^{\alpha}\mathrm{e}^{-\mu\delta r^{\alpha}} \quad (1)$$

The original formula (1) has considered the impact of wind direction on wind dispersal. However, according to the assumption, we have removed the effect of wind direction and added the effect of wind strength on wind dispersal. So we deleted θ from the formula (1), kept the other factors, and added β to represent the strength of the wind each month. As a result, we get a new equation named "Wind dispersal model" in formula (2) as follows.

$$F(r,\theta)=\frac{\alpha^2\left(\mu\beta\right)^{(2+\alpha)/\alpha}}{4\pi\Gamma\left(2/\alpha\right)}\mathrm{r}^{\alpha}\mathrm{e}^{-\mu\delta r^{\alpha}} \quad (2)$$

F(*r*) is the dispersal probability of dandelion, which represents the relative probability. The variable r is the density peak valued distance of dandelion.

α is the classification parameter based on the seed quality of the dandelion. According to the previous researches, when the mass of seed is light (less than 0.1 mg), the classification parameter is large and $\alpha < 1$, which represents a long-distance dispersal. When the mass of seed is heavy (more than 0.1 mg), the classification parameter is small and $\alpha > 1$, which represents a short-distance dispersal. When the mass of seed falls between the above two ranges, the classification parameter is medium and $\alpha = 1$, which represents a medium distance dispersal.

β is the wind strength.

μ is the distance coefficient, which is used to adjust the specific density distribution of seeds with different qualities in the same dispersal situation. The smaller the μ, the farther the seed dispersal distance. So the value range is $0 \le \mu \le 1$.

e and γ are the fixed coefficients.

2.1.2. Density Distribution of Seed Dispersal in Different Regions

There are significant climate and meteorological differences in China [5], for example temperate region, subtropical region and arid region. It is necessary to conduct a systematic analysis of wind disposal in different regions under the comprehensive consideration of different meteorological factors (such as wind, temperature, humidity, rainfall, etc.).

Figure 1. Three typical locations distribution in China.

For the selection of data sample locations, since there are some obvious differences in wind, temperature, and precipitation in different regions, while temperate, tropical, and arid regions have significant differences above, so that we choose three regions with different climate characteristics as the data source points. Beijing represents the temperate zone, Jiayuguan City in Gansu Province represents the arid zone, and Haikou City in Hainan Province represents the tropical zone.

The locations of the three sites on the map of China are shown below in **Figure 1**.

We searched the data of three consecutive years from 2020 to 2022 in the China Research Data Services. For the wind data, we have used the arithmetic mean value of January, February, March, June and December as the wind strength of a single month, and the wind strength of three consecutive years is calculated and used.

Then we use Python 3.1.12 to plot the density function distribution. To begin with, we define the distance coefficient $\mu = 0.5$ in Python. According to the systematic analysis of seed weight of different varieties of dandelion by Zhang Jian *et al.* [6], the 1000-grain weight of six different varieties of dandelion seeds is 0.4

Table 1. α and β value in different regions in the density distribution calculation.

Index	Regions	α	wind strength (β)				
			Jan	Feb	Mar	Jun	Dec
1	Beijing	1.2	1.7204	1.9412	1.9785	2.2222	1.8280
2		2.0					
3	Jiayuguan	1.2	1.6774	1.9294	2.4516	2.7444	1.7849
4		2.0					
5	Haikou	1.2	2.9462	2.7882	2.9892	2.7333	2.5699
6		2.0					

- 1.1 g, that is, the mass of a single seed is 0.4 - 1.1 mg, so that the value range of α must be $\alpha > 1$. We have two custom α values in Python, $\alpha = 1.2$ and 2.0. The values of β are shown in **Table 1** for the three-year wind averages for each month in each region.

We used Python to build the distribution of dandelion dispersal probability density. When $\alpha = 1.2$ and 2.0, the three-year wind average of Beijing in January, February, March, June and December is substituted, and the image is drawn. The meteorological data comes from the website https://www.tianqi24.com/ [7].

The axis-x is the dispersal distance coefficient r, and the axis-y is the dispersal probability $F(r)$ of dandelion. The number after each color represents its corresponding month, namely F1 for January, F6 for June, and F12 for December.

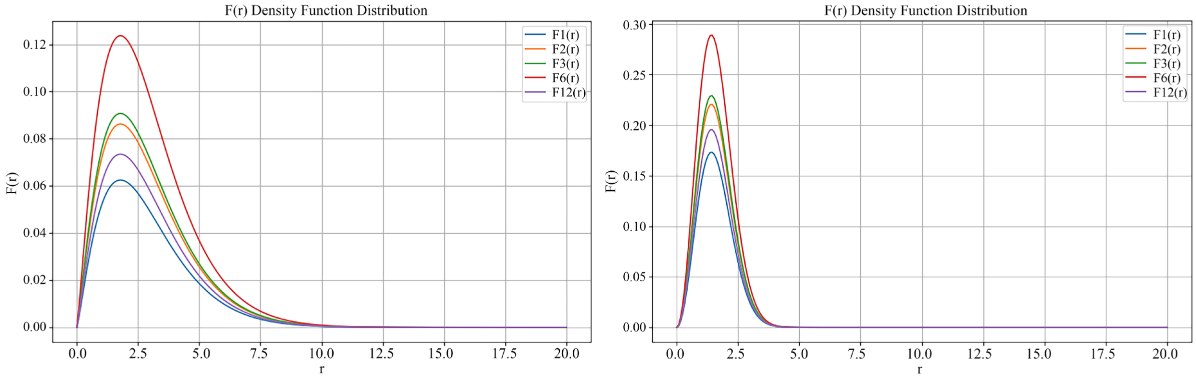
It is known that the dandelion will be blown to an open space with an area of one hectare, and a hectare is equal to 10,000 square meters, then the radius of a hectare is equal to 56.42 meters, and we will calculate it according to 60 meters.

To express clearly, the maximum value of the dispersal distance coefficient r is 20.0, and the real value corresponding to it is the radius of one hectare, that is, 60 meters, so we can reduce the calculation by three times with the same proportion.

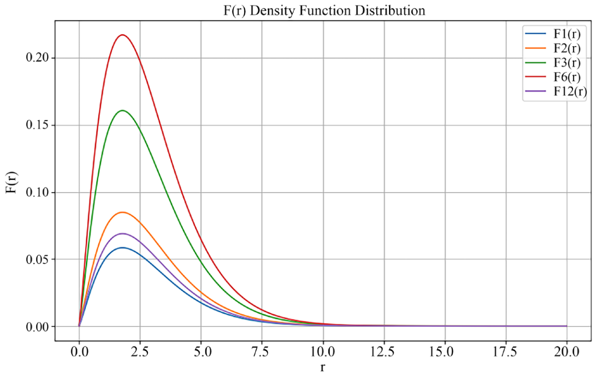
According to **Figure 2(a)**, when $\alpha = 1.2$, dandelion dispersal probability is highest in June and lowest in January. Given that the average wind in June is 2.22 and the average wind in January is 1.72, we can conclude that the dandelion dispersal probability F (r) is related to the wind strength β. As the wind strength is increasing, dispersal probability is increasing, while the dispersal distance under the highest probability is constant. And plus, the trend of these five lines is same.

When $\alpha = 1.2$, we compare **Figure 2(a)**, **Figure 2(c)**, and **Figure 2(e)** to find out that Haikou has the highest dispersal possibility, the second one is Jiayuguan, and the last one is Beijing. As a result, we know that the highest dispersal possibility is tropical region, and the lowest value is temperate zone.

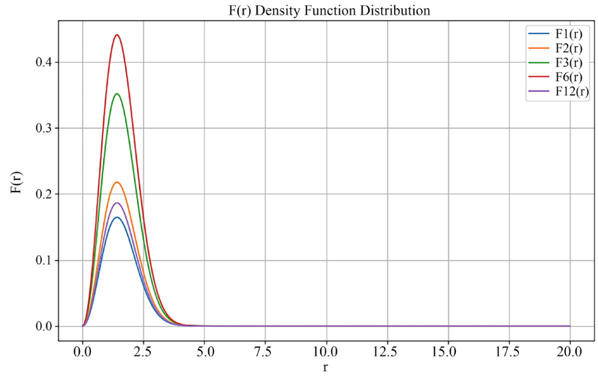
Comparing **Figure 2(a)** and **Figure 2(b)**, which show the images when $\alpha = 1.2$ and $\alpha = 2.0$ again, α changes the distance coefficient of dispersal of dandelion, while β changes the dispersal probability of dandelion.



(a) (b)



(c)



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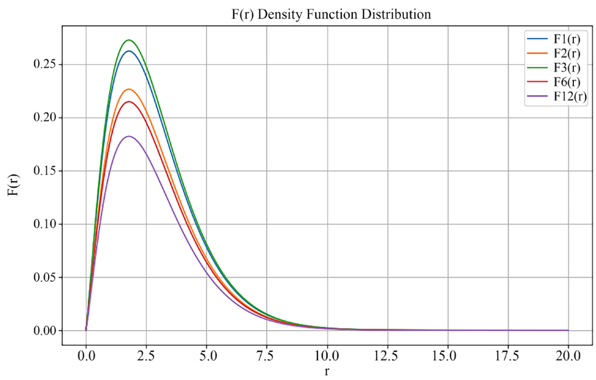
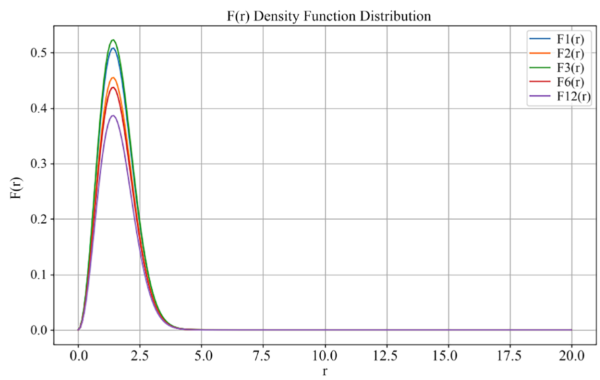


(e)



(f)

Figure 2. (a) Density Function Distribution of Beijing. $\alpha = 1.2$, $\mu = 0.5$, $\beta 1 = 1.7204$, $\beta 2 = 1.9412$, $\beta 3 = 1.9785$, $\beta 6 = 2.2222$, $\beta 12 = 1.8280$; (b) Density Function Distribution of Beijing. $\alpha = 2.0$, $\mu = 0.5$, $\beta 1 = 1.7204$, $\beta 2 = 1.9412$, $\beta 3 = 1.9785$, $\beta 6 = 2.2222$, $\beta 12 = 1.8280$; (c) Density Function Distribution of Jiayuguan. $\alpha = 1.2$, $\mu = 0.5$, $\beta 1 = 1.6774$, $\beta 2 = 1.9294$, $\beta 3 = 2.4516$, $\beta 6 = 2.7444$, $\beta 12 = 1.7849$; (d) Density Function Distribution of Jiayuguan. $\alpha = 2.0$, $\mu = 0.5$, $\beta 1 = 1.6774$, $\beta 2 = 1.9294$, $\beta 3 = 2.4516$, $\beta 6 = 2.7444$, $\beta 12 = 1.7849$; (e) Density Function Distribution of Haikou. $\alpha = 1.2$, $\mu = 0.5$, $\beta 1 = 2.9462$, $\beta 2 = 2.7882$, $\beta 3 = 2.9892$, $\beta 6 = 2.7333$, $\beta 12 = 2.5699$; (f) Density Function Distribution of Haikou. $\alpha = 2.0$, $\mu = 0.5$, $\beta 1 = 2.9462$, $\beta 2 = 2.7882$, $\beta 3 = 2.9892$, $\beta 6 = 2.7333$, $\beta 12 = 2.5699$.

In **Figure 2**, the results of the density distribution calculation when $\alpha = 2.0$ was always larger than the density distribution when $\alpha = 1.2$. To examine the most unfavorable conditions, the results of the density distribution calculation when $\alpha = 2.0$ was adopted in next impact factor analysis.

2.2. Impact Factor Analysis Based on Factor Analysis Model

2.2.1. Model Constructing

We used factor analysis method to establish a factor model that affects the growth of dandelion seeds. Because the space is three-dimensional, the propagation probability density will be determined by factors such as the seed coefficient represented by the weight of the seed, the wind level, and the propagation distance.

The factors in the model mainly consider natural conditions, such as temperature, precipitation, solar radiation, and wind, and the carrying capacity of the land. Among them, the first three factors (temperature, precipitation, and solar radiation) have clear effects on the growth of dandelion. The dispersal process caused by wind mainly refers to the dispersal times caused by multiple mature cycles. The ratio of the circular area to the total area obtained by the maximum probability of the dispersal model is used as the characterization method of the carrying capacity. Here, to calculate the area, we assumed there existed 1 hectare of "open space", wherein the absence of other species or natural predators is ensured [8].

We believe that the growth cycle characteristics and dispersal of dandelion will have an impact on the environment. And environmental and climatic conditions have an impact on the growth of dandelion, which in turn determines whether they can sprout, bloom, bear fruits, and ultimately spread out.

Existing seed dispersal methods include water-borne dispersal, animal dispersal and wind dispersal, among which wind is the most important long-distance dispersal mode. The wind-propagation model of seeds can be divided into two categories: phenomenal model and mechanistic model. According to the form of seed propagation core, the phenomenon model includes the short-tail model, the off-peak long-tail model, and the mixed propagation core model, which can achieve good results for the simulation of long-distance propagation data, and the mechanism model can be divided into two types: Euler convective diffusion model and Lagrangian stochastic model according to the simulation mechanism. The operating factors of the mechanistic model mainly include biological factors, meteorological factors, and topographic factors. The reference model used in this paper is a type of mechanistic model. In this section, we choose factor analysis model. The basic purpose of factor analysis is to use a few factors to describe the connections between many indicators or factors, that is, to group closely related variables into the same category, and each type of variable becomes a factor (called a factor because it is unobservant, *i.e.* not a specific variable), reflecting most of the information in the original data with fewer factors. In this part, we finished it by SPSS.

2.2.2. Variable and Data Sources (Table 2)

Table 2. Variable name, definition and source in factor analysis method.

Variable Name	Variable Abbreviation	Variable Definition	Variable Meaning	Data Sources
Temperature	Temp	If temp < 15˚C, Value = 0 If temp = 15˚C, Value = 1 If temp > 16˚C, Value = 2 …	According to the minimum temperature suitable for seed growth, the unit ˚C is 1, the larger the value, the more suitable for seed growth.	Chinese Research Data Services (CNRDS)
Daily Precipitation	D-Precipitation	Daily precipitation (mm/Day)	Reflecting rainfall.	https://www.tianqi24.com/historycity/
Solar Radiation	SR	Sunny = 4; Cloudy = 3; Overcast = 2; rain or snow = 1; If there are multiple weather conditions, take the worst-case weather as the value.	Reflecting solar radiation.	Chinese Research Data Services (CNRDS)

Continued

Diffusion Probability	D-probability	the maximum probability calculated according to this formula 2		Calculated according to this Formula 2.
Accumulated Dispersal Times	APt	Accumulated dispersal times at each time point	A seed maturity is recorded as a dispersal, reflecting the cumulative dispersal times at each time point.	Calculated based on plant characteristics.
Land Carrying Capacity	LCC	(the area of a circle using the distance with the highest dispersal rate as the radius)/ 1 hectare	Reflecting the impact of dispersal on land environment.	The distance with the highest dispersal rate is calculated according to this Formula 2.

1) Temperature

According to the previous researches of Ye Jingxue [9], dandelion seeds do not have dormancy phenomenon, and can germinate between 10˚C - 25˚C, and the optimum temperature for germination is 15˚C - 20˚C. When the temperature is above 30˚C, germination is slow and the optimum temperature for leaf growth is 20˚C - 22˚C. Therefore, when the variable temperature is equal to 15˚C, it will be valued as 1. When it is below 15˚C, its value is 0. When the temperature exceeds 15˚C, it will plus 1 every increase 1˚C in temperature.

2) Accumulated Dispersal Times

According to the previous researches of Zhang Junmin [10], dandelions need 6 - 10 days from sowing to flowering, and 1 - 2 months from germination to flowering. After flowered 10 - 15 days, seeds will mature. Taking the median of each interval, it is determined that the dispersal time from germination to seed maturity of dandelion is 56 days, and the maximum dispersal is 4 times in 2022.

3) Land Carrying Capacity

Land Carrying Capacity is the proportion of the circle area with the maximum probability dispersal distance as the radius in the empty space of 1 hectare. The reason for this calculation is that after the disposal of the plant, after the second round of diffusion, the circle area of the maximum probability of dispersal can no longer accommodate the growth of the seed disposal.

A dandelion planting is generally 700 - 1000 plants per square meter [11] [12]. A dandelion can produce more than 20 flowers, and each flower can produce more than 100 seeds, that is to say, a dandelion can produce more than 2000 seeds.

According to "wind dispersal model" in chapter 2.1, the maximum distance of dandelion dispersal probability is 3.75 meters. Therefore, in the second round of dispersal, the maximum distance of dispersal is 7.5, and a circle is formed with a radius of 7.5, with an area of 176.71 m^2, and the maximum seed capacity is 176.71 × 1000 seeds/m^2. As a result, the amount of seeds disposal in the second round is 2000 × 2000, which has exceeded the capacity of the regional circle.

2.2.3. Factor Analysis

The sample is daily data, with a range selected from Beijing, China from January 1, 2022 to December 31, 2022.

Table 3. The table of variable descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Temp	300	9.13	7.3725	0	22
D-Precipitation	300	25.7703	30.2766	0	78.8
Wea	300	3.0867	0.7667	1	4
D-probability	300	0.1817	0.1036	0	0.305
APt	300	2.1467	1.4556	0	4
LCC	300	0.0297	0.0276	0	0.0707

Table 4. The table of total variance explained.

Factor	Unrotated factor			Rotated factor	
	Eigenvalue	Proportion	Cumulative	Proportion	Cumulative
Factor 1	2.29699	0.5968	0.5968	0.5444	0.5444
Factor 2	1.45347	0.3776	0.9744	0.4206	0.9651
Factor 3	0.22524	0.0585	1.0329	0.0649	1.0300
Factor 4	0.03567	0.0093	1.0422	0.0122	1.0422
Factor 5	−0.01250	−0.0032	1.0389		
Factor 6	−0.14981	−0.0389	1.0000		

Table 3 presents the descriptive statistical results of the variables.

According to the Chinese agricultural planting network [13], the production habit of dandelion, the optimal temperature for seed germination is 15˚C - 25˚C, and the germination time is recorded as the beginning of two consecutive occurrences of 15˚C from January. According to the temperature in Beijing, the germination temperature requirements will be met from March 7, 2022. Total sample size 300 because of temp < 15˚C. As shown in Table 3, descriptive statistical shows that there are 300 final samples, the mean and standard deviation are given, and D-Precision has a relatively large standard deviation, which indicates a relatively large fluctuation range. However, that there are no outliers.

KMO test is 0.5367 and larger than 0.5. This indicates suitability for factor analysis.

Variance interpretation rate is the amount of information extracted from factors. We extract two component factors, according to Eigenvalue values greater than 1, the cumulative contribution rate of variance is 0.9651 (Table 4).

After factor rotation, the new factor loading coefficient can be made as far away from zero or as close to zero as possible, thus clarifying the meaning of the factor more clearly (Table 5).

Factor1 includes two indicators, APt reflects the cumulative number of times dandelion has been diffused, which is determined by the seeds from germination to fruiting, ripening, and dispersal; LCC reflects Proportion of area in 1 hectare, this area is a circle using the distance with the highest dispersal rate as the radius,

Table 5. Rotated factor loadings (pattern matrix) and unique variances.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Uniqueness
Temp	−0.3181	0.7662	0.1070	0.1477	0.2784
D-Precipitation	−0.1545	0.5647	−0.2510	0.0857	0.5869
Wea	0.1040	−0.1024	0.4001	0.0336	0.8175
D-probability	0.1333	0.8129	−0.1207	−0.1233	0.2916
APt	0.9925	0.0717	0.0030	−0.0371	0.0083
LCC	0.9781	−0.1910	0.0286	0.0044	0.0059

which is determined by dispersal distance. This distance is related with weight of seeds and wind intensity, this is calculated using "wind dispersal model" in chapter 2.5. So, both factors are determined by the properties of the dandelion, so Factor 1 characterizes the plant attribute factor.

Factor 2 includes temperature, day-Precipitation and dispersal probability. Dispersal probability depends on the wind strength. Therefore, Factor 2 represents climatic environmental conditions.

According to Table 4 and Table 5, we can get:

Total Daily Impact Score = (0.5444/0.9651) × Factor 1 + (0.4206/0.9651) × Factor 2 = 0.5641 × Factor 1 + 0.4358 × Factor 2

Compared with climate and environmental conditions, plant attribute factors have more important influence on the environment.

The daily impact image trends are shown in Figure 3.

The impact of dandelion on the environment presents a cyclical phenomenon, which is consistent with the growth cycle of dandelion in 2022. There are four seed diffusion periods, and the impact of each diffusion on the environment will show a jump increase. Moreover, the climate and environmental conditions in Beijing, China from May to August are very suitable for the growth and disposal

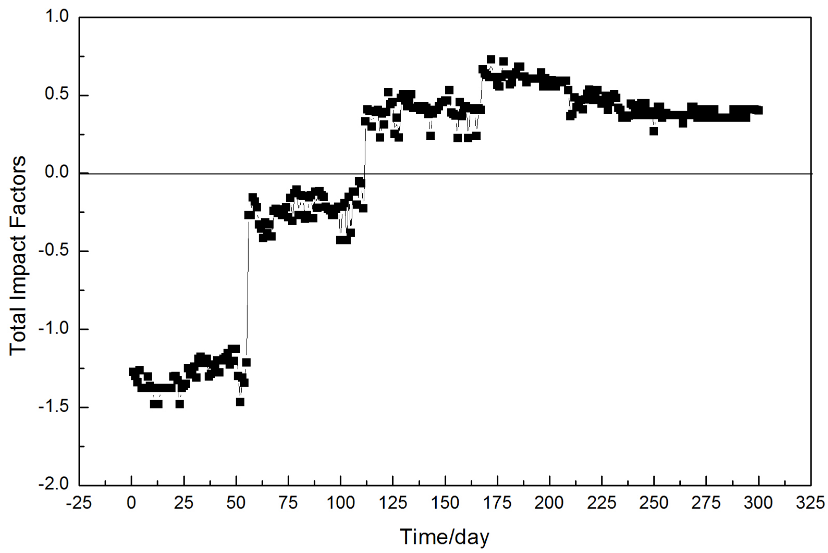


Figure 3. The graph of total impact factors of dandelion.

Table 6. The table of variable weight.

Variable	Weight
Temp	7.08%
D-Precipitation	6.20%
Light	1.79%
D-probability	18.19%
APt	46.35%
LCC	20.39%

of dandelion. However, the influence gradually decreased and stabilized after the last transmission period, because the climate gradually turned cold in October, and the temperature, rain, and light were not suitable for dandelion to continue to germinate.

According to Table 4 and Table 5, we can calculate the weight of each indicator (Table 6).

Temp = (−0.3181 × 0.5444 + 0.7662 × 0.4206 + 0.1070 × 0.0649 + 0.1477 × 0.0122)/1.0422 = 0.1514

And so on, you get:

Precipitation = 0.1326

SR = 0.0383

D-probability = 0.3887

Apt = 0.9906

LCC = 0.4357

After the weight normalization processing:

Temp = 0.1514/(0.1514 + 0.1326 + 0.0383 + 0.3887 + 0.9906 + 0.4357)

According to the weight, the biggest influence on the environment is the number of seed dispersal cycles, accounting for 46.35%, followed by the disposal area, accounting for 20.39%.

2.2.4. Application for Other Two Species Except for Dandelion

The one species we have chosen is *Solidago decurrens* Lour. It generally sprouting in spring, beginning to germinate in March every year, from June to December for the flowering and seed stage, from seed germination to flowering 60 days, the cycle is the same as dandelion; the seeds weigh 0.05mg each, < 0.1mg, which is a lightweight, unlike dandelion (dandelion is a heavyweight).

Table 7. The table of basic info for three species.

No.	Name	dispersal cycle	Seed weight	Classification
1	dandelion	56 (day2)	2 mg	>0.1 mg, heavy weight class
2	*Solidago decurrens* Lour.	60 (days)	0.05 mg	<0.1 mg, light weight class
3	*Senecio vulgaris* L.	90 (days)	0.23 mg	>0.1 mg, heavy weight class

Table 8. Total variance of explanation (*Solidago decurrens* Lour).

Factor	Unrotated factor			Rotated factor	
	Eigenvalue	Proportion	Cumulative	Proportion	Cumulative
Factor 1	2.37287	0.7166	0.7166	0.6958	0.6958
Factor 2	0.83820	0.2531	0.9697	0.1988	0.8946
Factor 3	0.20078	0.0606	1.0303	0.0891	0.9837
Factor 4	0.06546	0.0198	1.0501	0.0664	1.0501
Factor 5	−0.03427	−0.0103	1.0398		
Factor 6	−0.13163	−0.0398	1.0000		

KMO test value is 0.5513 and larger than 0.5.

Table 9. Rotated factor loadings (pattern matrix) and unique variances (*Solidago decurrens* Lour).

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Uniqueness
Temp	−0.3759	0.6241	0.0449	0.0831	0.4603
D-Precipitation	0.0658	0.3095	0.4017	0.0828	0.7317
Wea	−0.1356	−0.0889	−0.3291	−0.1443	0.8446
D-probability	0.4804	0.3587	0.1141	0.4128	0.4517
APt	0.9807	0.0409	0.0951	0.1198	0.0132
LCC	0.9733	−0.1870	−0.0380	−0.0197	0.0158

Another species is called *Senecio vulgaris* L. The weight of each seed is 0.23 mg > 0.1 mg, which belongs to the heavyweight, the same as dandelion seed, but much lighter than the seed weight of dandelion (2 mg); from seed germination to flowering 90 days, longer than dandelion time. As shown in Table 7.

Consistent with the above, factor analysis method is used to calculate the total impact of invasion on plant environment considering the same influencing factors (Table 8 and Table 9).

(1) *Solidago decurrens* Lour.

Total Impact Score on Day = (0.6958/0.8946) × Factor 1 + (0.1988/0.8946) × Factor 2 = 0.7778 × Factor 1 + 0.2222 × actor 2

Compared with climate and environmental conditions, plant attribute factors have more important influence on the environment.

The effect of *Solidago decurrens* Lour on the environment is consistent with that of dandelion (Figure 4). The difference is that the interval of cycle duration is relatively uniform, while the interval of dandelion is longer in the last period. In the last period of the year, the influence did not show a downward trend, which may be due to the hot climate in Haikou, China, which is suitable for plant growth.

(2) *Senecio vulgaris* L.

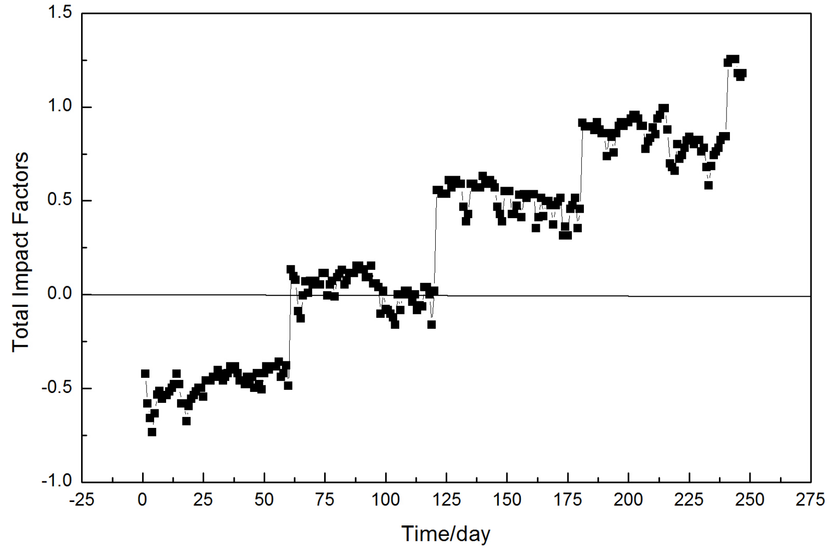


Figure 4. The Graph of total impact factors of Solidago decurrens Lour.

Table 10. Total variance of explanation (*Senecio vulgaris* L.).

Factor	Unrotated factor			Rotated factor	
	Eigenvalue	Proportion	Cumulative	Proportion	Cumulative
Factor 1	2.34771	0.7060	0.7060	0.6995	0.6995
Factor 2	0.99607	0.2995	1.0055	0.2825	0.9820
Factor 3	0.22096	0.0664	1.0720	0.0900	1.0720
Factor 4	−0.03334	−0.0110	1.0619		
Factor 5	−0.08152	−0.0245	1.0374		
Factor 6	−0.12448	−0.0374	1.0000		

KMO test value is 0.6069 and larger than 0.5.

Table 11. Rotated factor loadings (pattern matrix) and unique variances (*Senecio vulgaris* L.).

Variable	Factor1	Factor2	Factor3	Uniqueness
Temp	−0.4198	0.6454	−0.0513	0.4046
D-Precipitation	0.0198	0.3729	0.3594	0.7314
Wea	−0.1078	−0.0436	−0.3602	0.8567
D-probability	0.4785	0.5854	0.1721	0.3987
APt	0.9771	0.1154	0.0860	0.0246
LCC	0.9769	−0.1608	−0.0253	0.0192

We can get:

Total Impact Score on Day = (0.6995/0.9820) × Factor 1 + (0.2825/0.9820) × Factor 2 = 0.7123 × Factor 1 + 0.2877 × Factor 2

We come to the same conclusion that plant attribute factors are more important to the environmental impact than climatic and environmental condition factors (**Table 10** and **Table 11**).

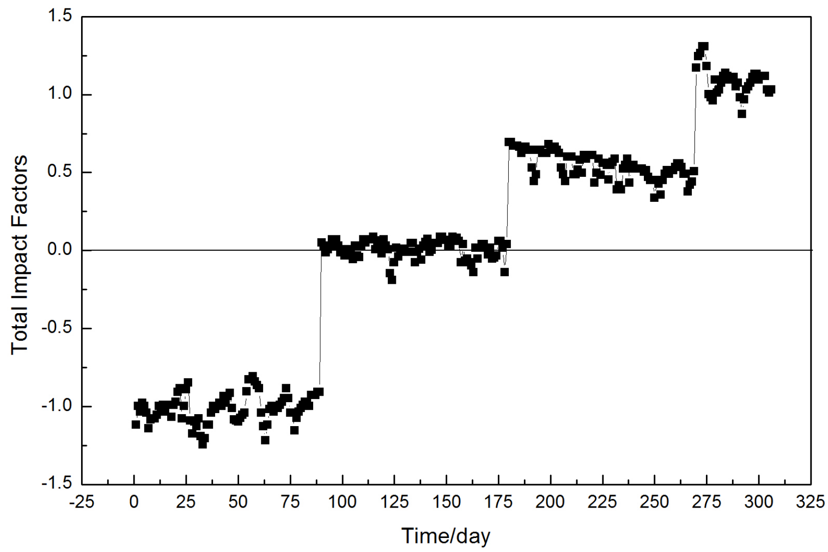


Figure 5. The Graph of total impact factors of *Senecio vulgaris* L.

Consistent with the above (**Figure 5**), the impact on the environment is cyclical. Each cycle lasts longer, which is not the same as before, maybe its dispersal cycle is long than others.

3. Conclusions

Seed dispersal is a key link in plant migration, and wind is an important factor affecting the distance of seed dispersal. And, Dandelion exemplifies a prototypical wind-dispersed plant species, yet there remains a dearth of research investigating the influence of varying wind velocities on the dispersal distance of its seeds across diverse climatic conditions. And so, Dandelion is the object of study in this paper.

To increase the precision of the model, we refer to the conclusions of some research papers and make corrections according to the actual situation. Wind strength is introduced as the main factor affecting seed dispersal, and wind strength data of Beijing, Jiayuguan and Haikou are selected according to its characteristics of tropical, temperate, and arid regions in China, so that we choose three regions with different climate characteristics as the data source points.

We can conclude that the dandelion dispersal probability $F(r)$ is related to the wind strength β. As the wind strength is increasing, dispersal probability is increasing, while the dispersal distance under the highest probability is constant. Haikou has the highest dispersal possibility, the second one is Jiayuguan, and the last one is Beijing. As a result, we know that the highest dispersal possibility is tropical region, and the lowest value is temperate zone. And plus, the trend of these five lines is same.

We selected five influential factors, namely temperature, precipitation, solar radiation, wind, and land carrying capacity. The dataset consists of daily data collected in Beijing, China from January 1st to December 31st, 2022. Utilizing a factor analysis model, we identified two key factors: Factor 1 representing plant attributes and Factor 2 representing climatic environmental conditions. Notably, the impact of Factor 1 surpasses that of Factor 2 and exhibits cyclical patterns due to seed growth cycles.

According to the seed weight parameter, we selected two other plants to simulate the probability of seed disposal distance and the law of seed growth and disposal. The one species we have chosen is *Solidago decurrens* Lour. Another one is *Senecio vulgaris* L. *Senecio vulgaris* L.'s impact on the environment is cyclical. Each cycle lasts longer, which is not the same as before; maybe its dispersal cycle is long than others. And therefore, the conclusion was the same as that of dandelion, both showed periodic changes. And plant attribute factors have more important influence than climatic environmental conditions. Therefore, for dispersal of seeds, as the sample selected in the paper is concerned, plant attributes play the key role, and more attentions should be paid to improve the plant attributes to enhance the dispersal of seeds.

Acknowledgements

This paper is an achievement of the High School Mathematical Contest in Modeling (HiMCM) in 2023. Thanks for the National Council of teachers of Mathematics.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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