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Original Paper

Invasive Studies of Dandelion and other Alien Species Based on Predictive Models

Xizi Pan, Tianjie Xiang, Tianyi Huang, Bo Pang
Chengdu No.7 Middle School International Department, 610095, China

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Abstract

Taraxacum officinale is a plant commonly known as the dandelion. It is a perennial herb native to Eurasia but has been introduced to other parts of the world and is now considered a weed in many areas. Dandelions are used in traditional medicine to treat various ailments and are also used as a food source in some cultures. However, some people regard it as an invasive species, which is a species that is harmful to the biological chain. Some suggest a reason: the dandelion's reproductive rate and ability to survive are so strong that it can easily encroach on the territory of other species, causing their numbers to decline.

To protect the whole ecosystem, we need to protect other species from being invaded by dandelions. Therefore, the first problem analyzed is the spread of dandelions, and the main idea for the first problem is the ***Sprawl prediction-based model****. The influence of different environmental factors on the spread of dandelions was considered to predict the number of dandelions after a certain time.*

The second model is the ***Logistic model****, which considers the competition relationship and also uses MATLAB to draw the image. Showing the relationship between the number of dandelions and that of another species. With some knowledge of the spread and a detailed analysis of the danger of dandelions to other species, we hypothesized two main species and counted their numbers to determine the impact of dandelions. Finally, our group inquired about the concept of invasive species to further analyze whether dandelions fit.*

Keywords

Invasive species, Logistic Model Sprawl Prediction-based model

1. Introduction

1.1 Problem Background

Taraxacum officinale, a kind of dandelion, usually has yellow flower heads, and such “heads” turn into round balls and they can be blown apart by the wind. These balls are called ‘clocks” or “blowballs”. The look of dandelions is shown in Figure 1.

Figure 1. Different Kinds of Dandelions

Dandelion is a common plant in temperate and subtropical zones. Originally from Eurasia, this plant was introduced to the Americas and Australia, so it can now spread all over the world. It has an interesting structure, with each seed attached to a parachute-like structure called a "leaf pillow", which is conducive to wind travel. Therefore, dandelion survival and reproduction ability is very strong.

1.2 Problem Restatement

Nowadays, many people have learned that dandelions are good for people. Dandelions can be eaten, even raw. Moreover, it can be made into an important component to provide nutrition for the human body. Despite all that has been learned about the benefits of dandelion, many people still firmly believe that dandelion is a harmful invasive species. The main reason why people have this idea is that the vitality of dandelion is too strong. Because of its high reproductive capacity, when it migrates to new locations and settles down, it is difficult not to be seen as a plant that is harmful to the local ecology or superfluous.

1.3 Our Work

Our team analyzed whether dandelions are the enemy of mankind. First of all, we have a certain understanding of the dandelion's reproductive ability. This point is concretely presented in the first question. We built a mathematical model to predict the spread of dandelion in different periods, and in the process of analysis, we made sure that the model was consistent with the real environment, including temperature, humidity, rainfall, and other conditions.

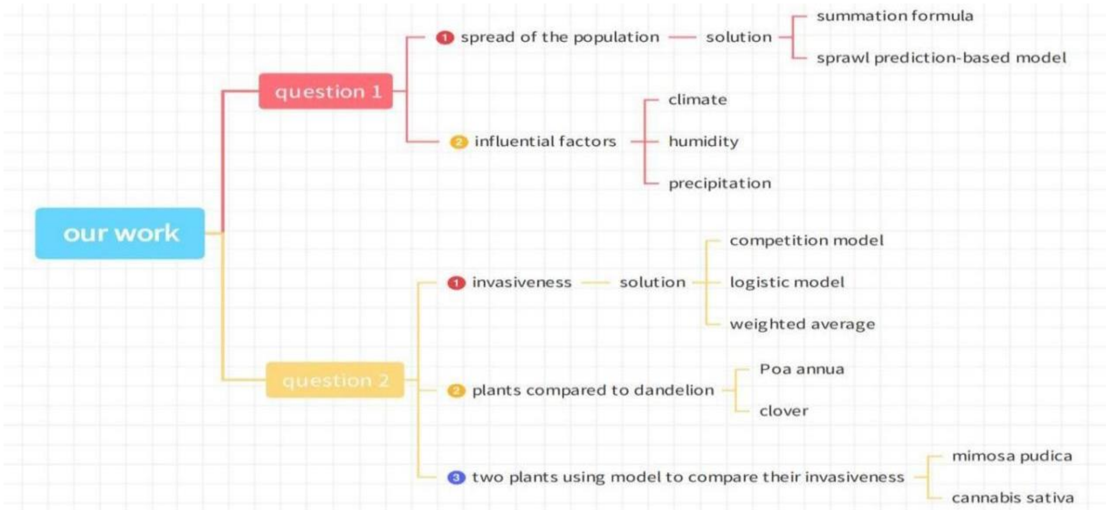


Figure 2. Mind Map of the Paper

Then, in the second question, we built a Sprawl prediction-based model to determine the impact factors of invasive species and used it to calculate the impact factors of dandelions.

In this part, we build 4 models to analyze whether dandelions should be considered an invasive species. In the first question, we focused mainly on predicting the spread of dandelions. Previously, it had been known that the biggest reason why dandelions were considered harmful was that they spread too quickly. Therefore, to make the spread rate more specific, we built a model to analyze the spread of dandelion within 1, 2, 3, 6, and 12 months respectively. In the second question, we built a model to analyze the impact factors of dandelion. The model should integrate multiple variables, including the characteristics of the plant and the nature and extent of the harm it poses to the environment.

2. Assumptions

Assumption 1: In the model for predicting the spread of dandelions, we selected four landmark directions, which are easy to calculate and can summarize most of the range, so that our prediction model can accurately show the size of the area where dandelions can spread within a certain time range.

Assumption 2: The factors that affect plant growth and seed spread are so extensive and complex that the three factors that have the greatest influence - temperature, humidity, and precipitation - are included in the discussion, and other factors are chosen to be ignored because of their small influence.

Assumption 3: Assuming that the tiny amount of dandelion likely to grow is not taken into account, this allows us to narrow down our calculations appropriately and does not have much effect on the accuracy of the prediction.

Assumption 4: Assuming that only one plant other than dandelion has a competitive effect on dandelion, we can better use the model to determine dandelion invasiveness. When dandelions grow, only one other invasive plant, the yellow flower chrysanthemum, grows alongside the dandelion to compare the dandelion's invasive ability. Due to the complexity of plant species growing in a particular area, it is easy to calculate an accurate value to reduce the influence of other factors.

3. Symbols, Definitions, and Terminology

3.1 Symbols and Definitions

Table 1. Symbols and Definitions

Symbols	Meanings
	Total population
	The initial number of dandelions
()	Temperature
()	Humidity
()	Precipitation
	Fatality rate
()	Wind velocity
	Growth rate
,,	Weight of
,,	Weight of
	The number of lattices
	constant
	historical value after normalization
+	value of the weighted mean

3.2 Terminology

The following are the technical words that will appear in this article, and they are explained by consulting the sources.

- **Humidity:** Humidity indicates how dry and wet the air is, that is, the physical quantity of water vapor contained in the air. In the calculations, we use relative humidity for the calculation.
- **Temperature:** Temperature, which measures the temperature of the growing environment of the three plants tested in the model, in degrees Celsius.
- **Growth rate:** Indicates how much the dandelion grows each month compared to the previous month, expressed as a percentage.
- **Lethality:** The percentage of new dandelions that die during the next month's growth.
- **Invasive species:** Determined by the government to be invasive, we selected severe invasive and general invasive species in the modeling.

4. Ability to Reproduce and Influence

4.1 Model 1: Sprawl Prediction-based Model for Question 1

To study the extent to which dandelions spread, we first need to determine the amount of dandelions that can spread.

First, we establish that time (month) is the independent variable, and the change in the number of dandelions is considered in*t* [0,12] .

To calculate the number of dandelions at *t* instantaneous time, you can find the number of dandelions at the time before *t* instantaneous time, and multiply it by the increase after *t-1* time period.

$$N_t = (N_{t-1} + p\widetilde{N_{t-1}})(1 - \sigma_{t-1}) \tag{1}$$

The above formula: N_t indicates the number of dandelions at time t; N_t indicates the start and end time, N(0) indicates the number of dandelions; p: The number of seeds produced per dandelion plant $\widetilde{N_{t-1}}$ theoretically. indicates the number of dandelions that can spread seeds at time t-1. We now use P to represent the maturity of each σ_{t-1} dandelion. And is the lethality of dandelion seeds.

$$\widetilde{N_{t-1}} = \left\{ \sum_{n=0}^{N_{t-1}} P_{t-1}^{n} \mid P_{t-1}^{n} > 1 \right\} \tag{2}$$

The formula P_{t-1}^{n} indicates the maturity of the nth seed at time t-1.

Second, to better match the reality of the situation, our group identified the conditions that would affect the growth of dandelions. First, climatic conditions. The climatic conditions, represented by A, are subdivided into four types, temperate a_1, arid a_2, Tropical a_3, and cold a_4. Among them, the temperate zone and cold zone are the best growth conditions for dandelions. When it comes to climate conditions, temperature T(t), is also one of the most important factors. The search data shows that when the temperature is less than 30 degrees Celsius, the dandelion reproduction rate is normal. When the temperature is higher than 30 degrees Celsius, the growth rate of dandelion is significantly slower. Second, humidity H(t), is also an important factor. Humidity is the physical quantity of how much water vapor contained in the air, which is used to express the degree of dry and wet air. The final factor to consider is precipitation F(t).

Assuming that the above-influencing factors are all negative influencing factors, the number of spores of a dandelion plant is P. The number of dandelions a plant can produce is equal to its number of spores. The growth rate is the value less than 1, expressed as a percentage.

Three factors cause dandelion death: temperature, humidity, and precipitation.

So the mortality rate of dandelions is expressed as:

$$\begin{cases} \sigma_i(t) = a_i T \beta_i H \gamma_i F \\ i = 1, 2 \end{cases} \tag{3}$$

In this formula, means the two sets of data need to be brought in separately. ,, means the weight of the three variables in the above formula.

Mortality is also a number less than 1 expressed as a percentage. The coefficient is different due to the different influences of climate on temperature, humidity, and precipitation.

Next, let's say the number of dandelions is N, and the initial number of dandelions is N_0.

The instantaneous number of dandelions at a given point in time is equal to the number of dandelions that would have grown plus the number of dandelions that would have died without being affected by any of the three causes.

Table 2. Influence Factors

	Temperature	Precipitation	Relative Humidity
Tropical	30℃	1000mm	75%
Arid	50℃	Almost zero	20%
Temperate	20℃	2000-3000mm	70%
Cold	0-10℃	300mm	60%

From the above chart, the values are calculated by bringing in the data corresponding to each region.

After analyzing the influence of various factors on the spread of dandelion, the focus was on the influence of wind. Dandelion breeding depends on the wind, the wind blows the seeds and spreads them everywhere. Therefore, our group shared specific information about the impact of wind speed and direction on the spread.

Assume that the land within a hectare is divided into equal numbers of (to be determined) grids, and if there is dandelion spread within a grid, it is considered to be spread, and the wind direction is random and fixed every month, consistent with the actual direction, and the grids between the starting point and the endpoint in the direction of southeast, northwest are considered to be spread. And we calculate the region that is spread by wind speed .

We have this formula for wind speed:

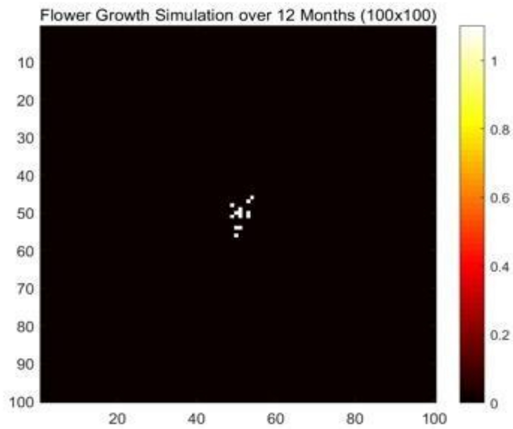
$$\theta(t) = a_i T + \beta_i H + \gamma_i F \tag{4}$$

Moreover, the relation between wind speed and spread area is as follows:

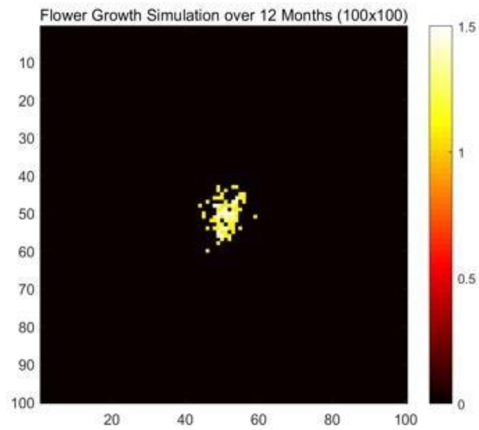
$$s = \frac{k}{\theta(t)} \tag{5}$$

Among them, the area represents the propagation distance of a dandelion seed, and according to the data, it can be seen that with the increase of $\theta(t)$, wind speed the propagation distance of the dandelion decreases, so we use the inverse relationship to fit the relationship between the two, and k is the inverse coefficient.

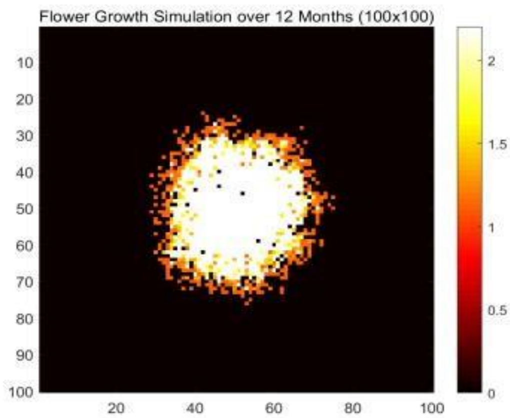
Finally, according to the models we established for each influencing factor, MATLAB programming was used to predict the spread degree of dandelion within 1, 2, 3, 6, and 12 months, respectively. After 12 months, the number of dandelions will reach 6,437,174.



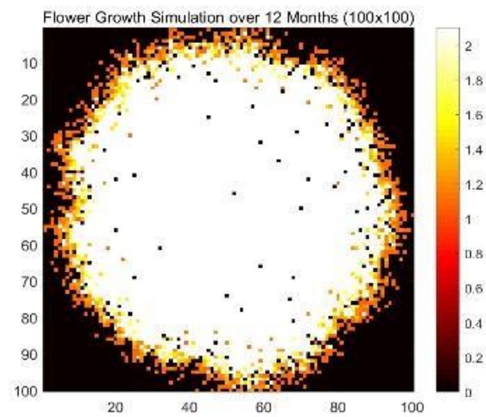
(a). After 1 month



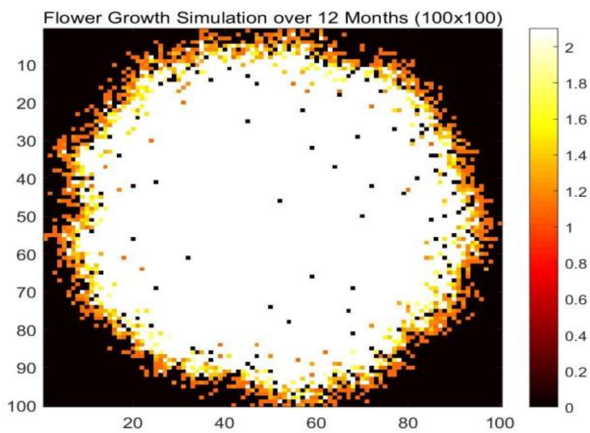
(b). After 2 months



(c). After 3 months



(d). After 6 months



(e). After 12 months

Figure 3.

The white area means that the number of dandelion seeds is already greater than two. We planted the mature dandelions in the place (51 51) and spread them a little bit around in the first month. The seeds that ripen in the second month still do not show any significant change.

In the third month, there is a slight change in the number of changes, with each increase in the location of the spread. In the sixth month, the number of dandelions spreading to surrounding areas increased significantly.

4.2 Model 2: Influence Factors of Dandelion

Due to the invasiveness of the plants, Poa annua is determined as another invasive plant that is growing with dandelion, to simplify things, it is assumed that only Poa annua and dandelion grow in one-hectare area.

There is a regular pattern for plants to grow in a one-hectare area. To see the effect of dandelion on other species, one need only calculate the variable of Poa annua species. The classical model of population change is the logistic model. In an ideal situation, population change is carried out in an exponential growth mode. Also, when the dandelion and Poa annua each grow without interference from another plant, both plants should follow the logistic model.

4.2.1 Logistic Model

A logistic model is a statistical model that is used to analyze and predict the relationship between a binary dependent variable and one or more independent variables. The model uses a logistic function to estimate the probability of the dependent variable being a certain outcome, which can be either 0 or 1. This type of model is commonly used in various fields such as economics, marketing, and healthcare to make predictions and decisions based on data analysis.

For the established model, we consider the competition among species, and it can be found that the number of species is the dominant species that eventually survive, while the inferior species are gradually eliminated.

Plant Poa annua and clover are chosen to compare with dandelion to determine dandelion 's invasiveness. The reason for choosing these two plants is they are all commonly found everywhere, and they are also being seen as invasive species in some areas. If the plant with no invasiveness has been chosen, the dandelion will be overwhelmingly superior to it, so the plant with no invasiveness will have no competitive ability to fight for its resources. Therefore, a plant' s invasiveness is necessary to measure dandelion's invasiveness.

There is a regular pattern for plants to grow in a one-hectare area, and when the dandelion and Poa annua each grow without interference from another plant, both plants should follow the logistic model. To find the number of instantaneous times at t, you need to use the derivative formula. The ratio of N to K is the number of people that can survive, and the final number can be obtained by multiplying the growth rate by the number before the instantaneous time.

$$\begin{cases} \frac{dN_j}{dt} = r_j N_j (1 - \frac{N_j}{K_j}) \\ j = 1,2,3 \end{cases} \tag{6}$$

N_1 is the population of dandelion in this area, N_2 is the population of Poa annua in this area, r_1 is the growth rate of dandelion, r_2 is the growth rate of Poa annua, K_1 is the environmental capacity of dandelion, K_2 is the environmental capacity of Poa annua.

Assume the land is full of nutrition and can offer both plants enough nutrition to grow. The environmental capacity of each plant is calculated by its coverage of land divided by the entire land, which makes it maximum to grow in the one-hectare area regardless of other influential factors. Under the same growth condition, it is assumed that the growth rates of two plants are the same.

But when the two plants growing together, the retardation effect of Poa annua toward dandelion is in direct proportion to Poa annua's total number in this area; the retardation effect of dandelion toward Poa annua is also in direct proportion to dandelion's total number in this area. It's the same idea as before, except this time we need to calculate two populations. Also subtract 1 from the ratio of number to maximum capacity to calculate the number of species that will eventually survive, and multiply by the growth rate.

$$\begin{cases} \frac{dN_f}{dt} = r_f N_f (1 - \frac{N_f}{K_f} - s_1 \frac{N_f}{K_f}) \\ j = 1,2,3 \\ f = 2,3 \\ \end{cases} \tag{7}$$

s_1 is the invasiveness of dandelion, and s_2 is the invasiveness of Poa annua.

The smaller the invasiveness of both the plants are, the stronger the invasive ability they will have.

Since the invasiveness of each plant varies from other plants, the invasiveness of dandelion and Poa annua are determined by weighted mean. Drought tolerance, seed reproduction, and PH value impact are included to compare to confirm their invasiveness. When each impact factor is timed by the weight of each factor, the partial weighted mean is calculated, after summing all parts, the entire weighted mean is calculated.

$$\hat{y}_{t+1} = \sum_{t=1}^{n} W_t \times y_t \tag{8}$$

The sum of the weight equals 1:

$$\sum_{t=1}^{n} W_t = 1 \tag{9}$$

y_t+1 is the value of the weighted mean, and Wt is the t th historical value after normalization. In order to get the invasiveness of different species, standardization is also needed. Differential standardization preserves the relationships present in the original data and it can also eliminate the influence of data value ranges. Since some data are represented in ranges.

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{10}$$

4.2.2 Dandelion Compared to Poa annua

Dandelion has a high drought tolerance when they grow up, one dandelion plant can produce 15000 seeds, and they are able to live in the soil whose PH value is between 4 to 8. Poa annua has a low drought tolerance but is able to experience fake death when they encounter extreme drought environments. One Poa annua plant can produce 20000 seeds, and they are able to live in the soil whose PH value is between 5.5 to 7. Drought tolerance is determined by the death rate of each plant, the smaller the rate is, the better the plant is able to tolerate drought.

Table 3. Index of Two Species

	Drought tolerance	**Seeds reproduction**	**PH value**
Dandelion	0.2	0.6	0.2
Poa annua	0.3	0.5	0.2

Table 3 represents the relationship between dandelion and Poa annua, using the method of partial means.

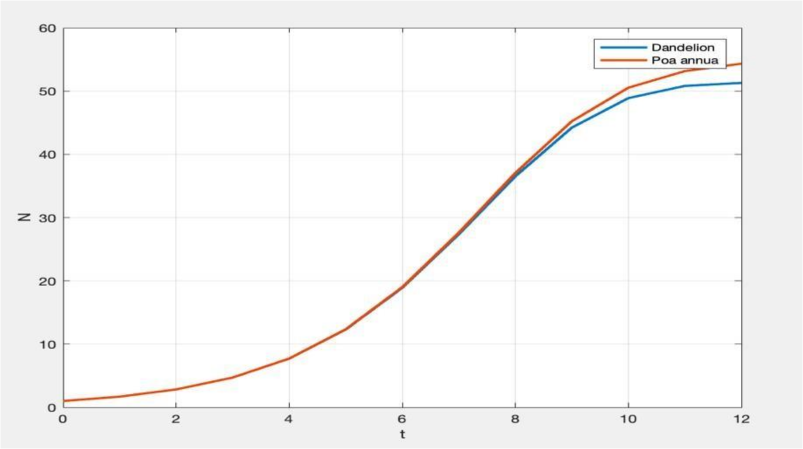


Figure 4. Dandelion and Poa annua Competition

But when the two plants growing together, the retardation effect of Poa annua toward dandelion is in direct proportion to Poa annua ’ s total number in this area; the retardation effect of dandelion toward Poa annua is also in direct proportion to dandelion’s total number in this area. s1 is the invasiveness of dandelion, and s2 is the invasiveness of Poa annua. The smaller the invasiveness of both plants, the stronger their invasive ability will be.

4.2.3 Dandelion Compared to Clover

In order to confirm the model, another plant, clover, is chosen to make the competitive model generalizable and representative enough to measure the invasiveness of other plants.

Clover is thought to have high drought tolerance, because they have some kind of protein in their body, which ensures them to get rid of some parts of water in their body but still keeps them alive. Dandelion has high drought tolerance only when they grow up. Therefore, in comparison, clover has a higher drought tolerance than dandelion. One clover can only produce an average of 5 seeds, but in the one-hectare region the number of clover seeds can only be measured by kilograms but not specific number of seeds, so in comparison to dandelion, clover has similar reproductivity as dandelion but the reproductivity is a little higher than dandelion. Clover can only live in soil whose PH value is between 5 and 8, which means it has a smaller range of PH tolerance compared to dandelion.

Table 4. Relationship between Two Species

	Drought tolerance	Seeds reproduction	PH value
Dandelion	0.3	0.4	0.3
Clover	0.2	0.5	0.3

Table 4 represents the relationship between dandelion and clover, using the method of partial means.

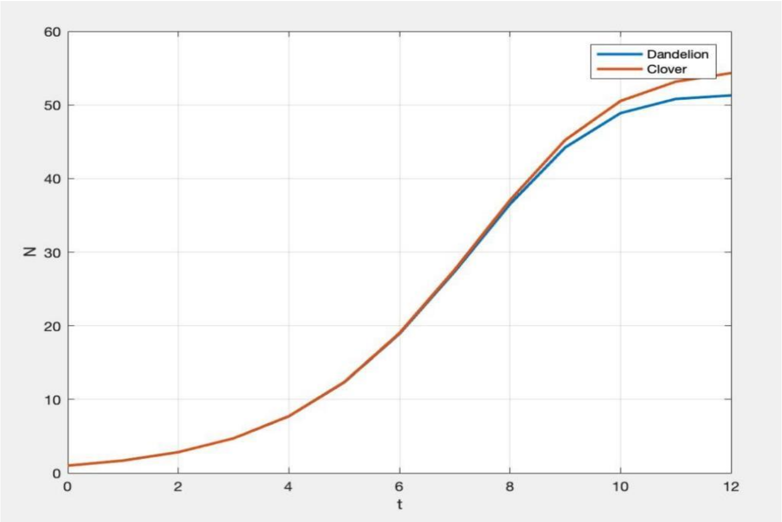


Figure 5. Dandelion and Clover Competition

After modeling, the relationship of invasiveness between them is clearly shown in the figure, which shows that they have similar invasiveness.

4.2.4 Plants Applied with This Model

After completing the model, two distinct species are introduced to put into this model to find the relative invasiveness. Mimosa pudica and Cannabis sativa. They are all invasive species but are regarded as invasive in different degrees. Mimosa pudica is regarded as a highly invasive plant, but Cannabis sativa is regarded as a low-invasive plant. This phenomenon can give a clear relationship between two plants.

Table 5. The Relationship between Two Species

	Drought tolerance	Seeds reproduction	PH value
Mimosa pudica	0.1	0.3	0.3
Cannabis sativa	0.3	0.5	0.2

Table 5 represents the relationship between Mimosa pudica and Cannabis sativa, using the method of partial means.

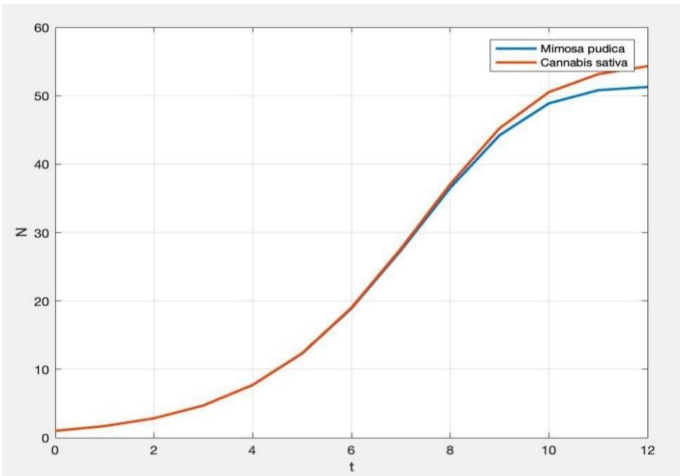


Figure 6. Mimosa and Cannabis Sativa Competition

After modeling, the relationship of invasiveness between them is clearly shown in the figure, which shows that they have similar invasiveness. Therefore, they have a small influence on each other.

4.3 Intrusive Determination

Table 6. Index of Two Species

	Mimosa pudica	Cannabis sativa
Drought tolerance	Not very drought tolerant	Resistant to atmospheric drought but not to soil drought
Number of seeds	6/root	3200/root
pH	Sandy loam, 5.5-7.5	Weakly acidic soils, 5.5-6.5

In the second question, we compared mimosa with cannabis, and as in the first question, we investigated their drought tolerance, the number of seeds, and the pH of the soil environment in which they grow. Among them, we found that mimosa is not very drought tolerant, each plant can produce 6 seeds, and the soil pH suitable for its growth is in the range of 5.5-7.5. At the same time, hemp is very tolerant to atmospheric drought, but not to soil drought, and can produce 3,200 seeds per plant. The pH of the soil suitable for the growth of cannabis is between 5.5-6.5.

5. Sensitivity Analysis

The following is a sensitivity analysis of the sprawl prediction model.

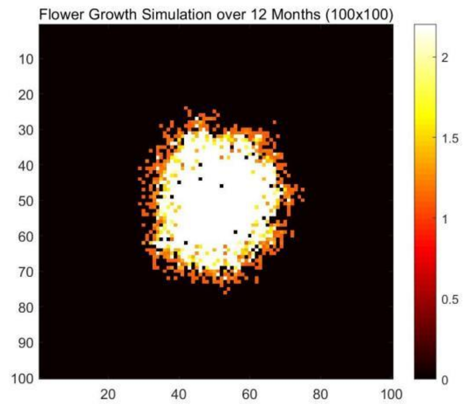


Figure 7. After 6 Months

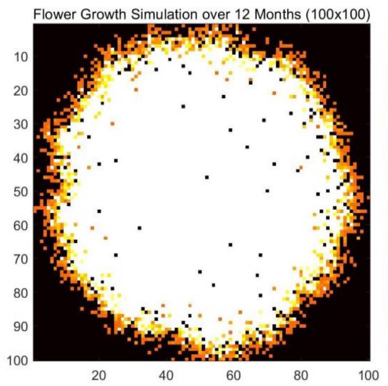


Figure 8. After 12 Months

If the value of v is 10, when the speed is 10, the number of ordinary workers around is significantly reduced.

When the value of d was 0.1, the number of mature dandelions increased, but there was no significant change in other areas.

This is the sensitivity analysis of the logistic model.

s_1=2 s_2=0.89

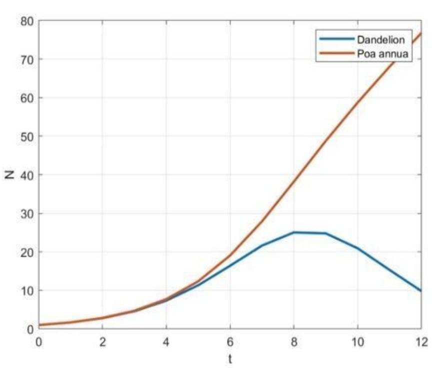


Figure 9. s_1=2, s_2=0.89.

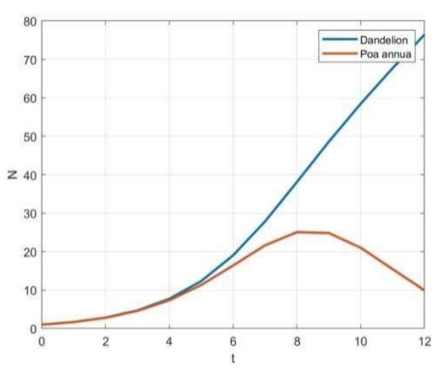


Figure 10. s_1=0.9, s_2=1.89

When s_1 or s_2 changed, the degree of marijuana invasion became higher.

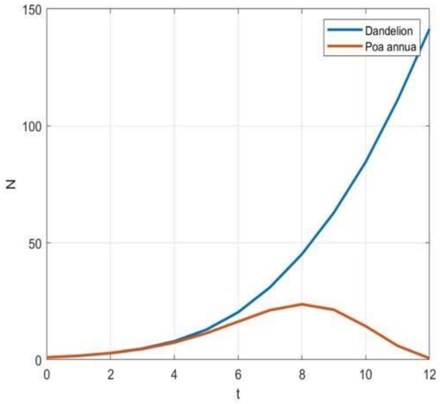


Figure 11. K_1=200, K_2=100

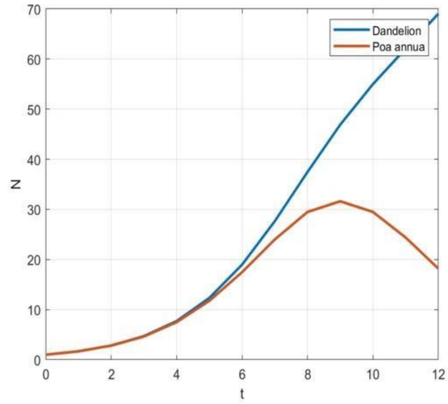


Figure 12. K_1=100, K_2=200

There is a significant increase in K1 and K2 a significant increase in a.

6. Advantages and Disadvantages

6.1 Advantages

We apply the Sprawl prediction-based model in the early stage and get an accurate result of curve fit.

We built and improved the Logistic model. Then we use a Logistic model to compare the invasive of each plant more accurately and determine whether they were invasive plants or not.

We divided the land into equal-sized chunks and calculated the area where dandelion seeds could spread, which made the model easier to calculate.

The model is stable, which is conducive to promoting innovation.

The Logistic model has low requirements for variables, and non-normally distributed data can be accepted.

The competitive model is brilliant in illustrating the relationship between two competitive species, it is suitable for presenting the relationship between dandelion and other species.

6.2 Disadvantages

We do not give, for example, the exact values of the influence of temperature, humidity, precipitation, etc. on the above modeling process.

We do not consider the abundance of wind directions, which may lead to a decrease in the accuracy of our forecasts.

We do not consider the other influences on the growth and dispersal of plants. That may bring some errors to our result.

The competitive model can only give the relationship between two species but cannot give specific data on the invasiveness of a specific species.

7. Model Improvement

The Competitive model can only give the relationship between two species but cannot give specific data on the invasiveness of a specific species, so if more specific data is given, a more specific relationship can be illustrated. So more specific data is what should be improved, and data that can measure a specific number of invasiveness can also be another improvement.

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Appendix

1 The spread of dandelions

```
function flower_simulation()
   % Initialize matrix with size 100x100
   matrix = zeros(100, 100);

   % Place the initial mature flower in the middle
   matrix(51, 51) = 1.1;

   % Simulation loop for 12 months
   for month = 1:12
      % Example v(t) and d(t) functions (can be replaced with actual functions)
      v_t = 20;  % Example: velocity function
      d_t = 0.15;  % Example: dying rate function

      matrix = spread_seeds(matrix, v_t);
      matrix = update_flowers(matrix, d_t);
   end

   % Display the final state of the matrix with improved visibility
   figure;
   imagesc(matrix);
   colormap(hot); % Use 'hot' colormap for better visibility
   colorbar; % Display colorbar for reference
   title('Flower Growth Simulation over 12 Months (100x100)');
   axis square; % Keep the aspect ratio square
   flowers = find(matrix > 0.1)
   Flowers = sum(flowers)

end

function matrix = spread_seeds(matrix, v_t)
   [rows, cols] = size(matrix);
   for i = 1:rows
      for j = 1:cols
         if matrix(i, j) > 1
            % Spread seeds
            for k = 1:15  % Spread 15 seeds
               % Preferentially choose closer distances
               distance = min(exprnd(v_t / 3), v_t); % Exponential distribution for distance
               angle = 2 * pi * rand();
               di = round(distance * cos(angle));
               dj = round(distance * sin(angle));
               new_i = i + di;
               new_j = j + dj;
               if new_i > 0 && new_i <= rows && new_j > 0 && new_j <= cols
                  matrix(new_i, new_j) = matrix(new_i, new_j) + 0.1;
```

```
                    end
                end
                % Ensure each flower can only spread once
                matrix(i, j) = -Inf;
            end
        end
    end
end

function updated_matrix = update_flowers(matrix, d_t)
    [rows, cols] = size(matrix);
    flower_indices = find(matrix > 0.1); % Indices of all flowers

    % Calculate the number of flowers to die based on the dying rate
    num_flowers_to_die = round(d_t * length(flower_indices));

    % Randomly select the flowers to die
    if ~isempty(flower_indices)
        flowers_to_die = randsample(flower_indices, min(num_flowers_to_die, length(flower_indices)));
    else
        flowers_to_die = [];
    end

    % Update growth for all flowers and set selected flowers to die
    for idx = 1:numel(matrix)
        if matrix(idx) > 0
            matrix(idx) = matrix(idx) + 0.3; % Update growth
        end
        if ismember(idx, flowers_to_die)
            matrix(idx) = 0; % Set selected flowers to die
        end
    end

    updated_matrix = matrix; % Assign the modified matrix to the output variable
end
```

2 Logistic Model

```
function [t, N1, N2] = population_competition(r1, r2, K1, K2, s1, s2, N10, N20, t0, tf, dt)
    t = 0:1:12;
    N1 = zeros(1, length(t));
    N2 = zeros(1, length(t));
    N1(1) = 1;
    N2(1) = 1;
    for i = 1:length(t)-1
        N1(i+1) = N1(i) + 1 * 0.7 * N1(i) * (1 - N1(i)/100 – 0.9 * N2(i)/100;
        N2(i+1) = N2(i) + 1 * 0.7 * N2(i) * (1 - N2(i)/100 – 0.86 * N1(i)/100);
    end
end
```

```
[t, N1, N2] = population_competition(0.7, 0.7, 100, 100, 0.9, 0.86, 1, 1, 0, 12, 1);
```

```
plot(t, N1, t, N2, 'LineWidth', 2), grid on, xlabel('t'), ylabel('N'), legend('Dandelion', 'Poa annua');
```

```
[t, N1, N2] = population_competition(0.7, 0.7, 100, 100, 0.475, 0.9, 1, 1, 0, 12, 1);
plot(t, N1, t, N2, 'LineWidth', 2), grid on, xlabel('t'), ylabel('N'), legend('Mimosa pudica', 'Cannabis sative');
```

```
[t, N1, N2] = population_competition(0.7, 0.7, 100, 100, 0.475, 0.9, 1, 1, 0, 12, 1);
plot(t, N1, t, N2, 'LineWidth', 2), grid on, xlabel('t'), ylabel('N'), legend('Mimosa pudica', 'Cannabis sative');
```