

Quantitative Analysis of Plant Population Quantity and Species Adaptation to Drought Based on Differential Dynamics Model

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Abstract: To address the impact of drought on species changes in plant communities, first, based on the weather data obtained in Area A, a Markov weather prediction model was constructed to simulate the changes in irregular weather in that area, and the probability of drought was found to be 54.73%. Then, a differential dynamics model was established to simulate the changes in plant populations, and ultimately the population changes with weather were obtained. Secondly, an optimization model was constructed from the population number to the total number of plants, and the optimal population number was obtained through numerical simulation. Thirdly, under the condition that other factors remain unchanged, the species number charts with weather changes are simulated, and the impact of different species types on the environment is analyzed. Thirdly, based on the above weather change results, increase or decrease the probability of dry weather factors, and obtain a change map of the number of species to analyze the impact on the environment. The research shows that when the pollution is light, the plant community will not be greatly affected, while when the pollution is serious, the plant population will degenerate. When habitat decreases, the growth rate of plant communities slows down.

Keywords: Plant community, Drought; Markov model, Differential dynamics, Simulated prediction.

1. Introduction

1.1. Problem Background

Drought is a common weather condition in some areas. The viability and response of different plant communities vary. There are also many levels of drought, and different plant communities show different responses to different levels of drought. And as the number of plant species increased, they were better able to cope with higher levels of drought than communities with just one plant species. The city A we studied has a temperate continental climate. The average annual temperature is 10.3°C, and the average annual precipitation is 360-400 mm, mainly from June to September.

1.2. Literature Review

Liang-liang Zhang et al. (2018) conducted a study on the impact of garden plant communities on summer microclimate characteristics [1]. Cen Yang et al. (2022) took the park green space in HuaiHua City, Hunan Province as an example to analyze the ability of plant communities to regulate microclimate comfort and its impact factors [2]. Dong-dong Duan (2022) conducted a study on the impact of drought and its soil legacy effects on the growth of typical grassland plants on the Loess Plateau [3], while Yu-lin Huang et al. (2022) provided an analysis on the impact of plant community characteristics on the microclimate in summer park shade space [4]. In this paper, based on the weather data obtained in Area A, we understand the probability of drought occurrence, establish a differential dynamics model to simulate changes in plant populations. From the population number to the total number of plants, we obtain the optimal population number through numerical simulation, and analyze the impact of different species types on the environment, in order to study the impact of changes in the number of species on the environment.

1.3. Restatement of the Problem

Considering the background information and restricted conditions identified in the problem statement, we need to solve the following problems: (1) Develop a mathematical model to address the changes of the same plant community in different weather conditions (sunny, cloudy, rainy, snowy and weather changes) and study their adaptation differences. (2) To further study the number of species in plant communities and how species types change their adaptability to arid environments. (3) For the first two problems, external factors, such as environmental pollution and habitat reduction, should be taken into account to analyze the impact on the plant community and provide methods to protect the long-term survival of the plant community.

2. Sources and Assumptions of Data

The data in this article is derived from Question A of the 2023 American College Student Mathematical Modeling Competition. In order to facilitate problem solving, the following assumptions are proposed: (1) The same plant has the same effect on other plants. In order to simplify the study of the model, the result of the problem is clearer. For example, let's assume that plant 1 has the same effect on plant 2 as plant 1 has on other plants. Each plant has the same effect on the other plants, but let's think about different plants having the same effect on the other plants. (2) For region A, the annual precipitation greater than 1200mm is not considered. The region A studied in this paper belongs to the temperate continental climate, with perennial drought and little rain. The main precipitation in Region A is only from June to September. Precipitation exceeding 1200mm is a small probability event, so we do not consider annual precipitation exceeding 1200mm.

3. Adaptation Differences of the Same Plant Community under Different Weather Conditions Based on Markov Chain Model

3.1. Research Ideas

For plant communities affected by drought, select precipitation, species type, species number, interplanting impact, environmental capacity, and pollution in dex. Firstly, Markov models are used to predict how the weather will change over time in the future. Precipitation is then used to

reflect varying degrees of weather change. Finally, a differential dynamics model is used to consider the effects of species interactions and species numbers on the prediction results.

3.2. Research Method

Weather conditions can be divided into many kinds, can be divided into sunny, cloudy, light rain, heavy rain, light snow and heavy snow, this weather is classified into four categories, respectively: sunny, cloudy, light, heavy [5] Weather Classification Standard is shown in Table 1.

Table 1. Weather Classification Standard

Number	Weather	Weather condition
0	Sunny	Clear, clear to cloudy
1	Cloudy	Cloudy, cloudy to sunny, cloudy to cloudy, cloudy to rain (snow)
2	Light	Light rain (snow), light rain (snow) to clear, light rain (snow) to cloudy, light rain (snow) to heavy rain
3	Heavy	Heavy rain (snow), heavy to torrential rain (snow), heavy rain (snow)

We set the state 0 for those with annual precipitation less than 200mm as arid zone (which is shown in Figure 1). When the annual precipitation is between 200mm and 400mm, it is set as state 1, which is semi-arid zone. When the annual precipitation is 400mm to 800mm, it is set as state 2, which is subhumid area. When the annual precipitation ranges from 800mm to 1200mm, it is set as state 3, which is a humid area

[6].



Figure 1. Annual precipitation 0 to 1200mm color scale plot.

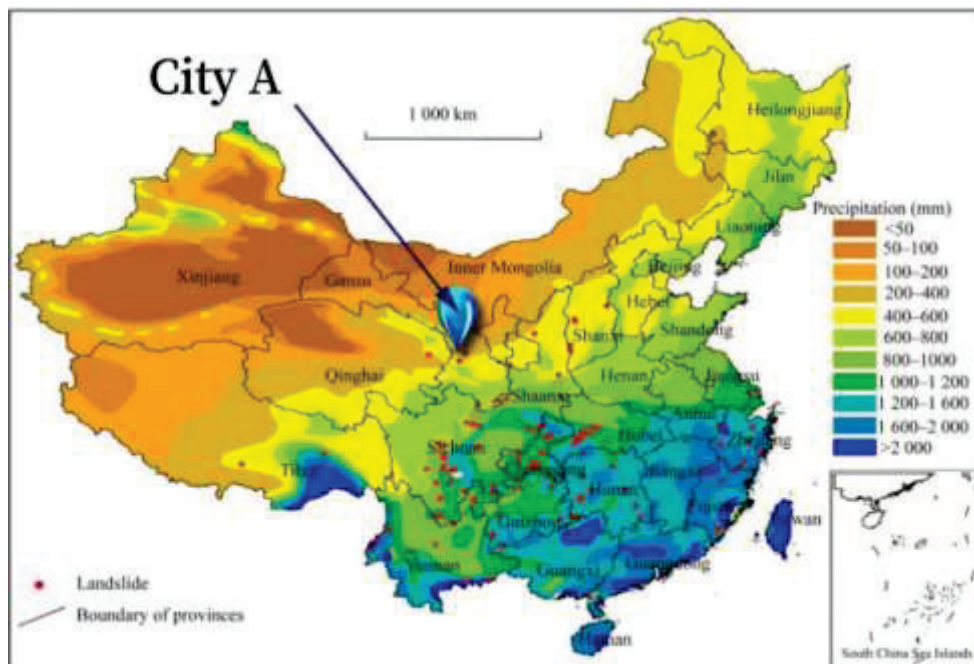


Figure 2. Annual precipitation distribution map of City A in the country.

The average annual precipitation of city A is shown in Figure 2. We study the typical Markov model of weather changes, and the conditions of a system at a given time in the future are only relevant to the present, not directly related to the past history. So we use Markov chain to predict the future weather, let $\{X_n, n=1,2,3,\dots\}$ be a random sequence, state space E is a finite or column able set, for any positive integer m, n, if $i, j, i_k \in E(k=1,2,\dots,n-1)$, where is as follow

formula (1):

$$P\{X_{n+m} = j | X_n = i, X_{n-1} = i_{n-1}, \dots, X_1 = i_1\} = P\{X_{n+m} = j | X_n = i\} = p_y(m) \quad (1)$$

It's called a Markov chain. It has no aftereffect.

3.3. Result Analysis.

According to the table 2, the weather transfer data is shown in Figure 3.

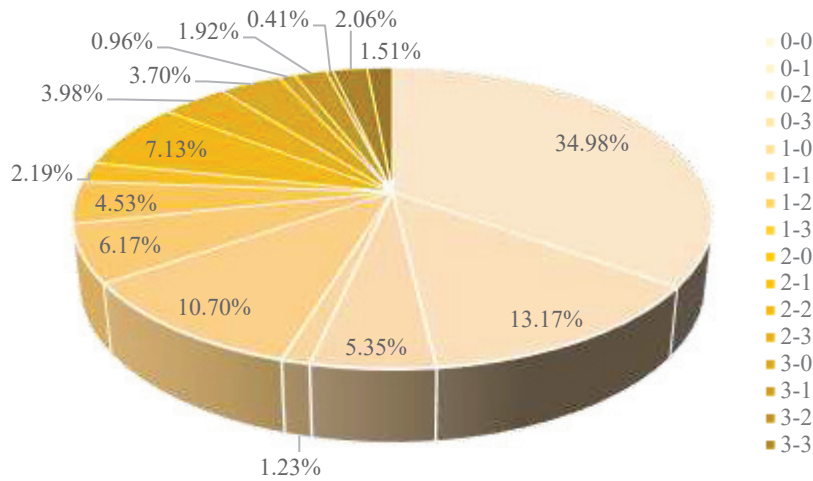


Figure 3. Statistical chart of weather conversion probability for Region A from February 2020 to February 2022.

The probability of obtaining the one-step transition matrix is as follow formula (2):

$$P^{(1)} = \begin{pmatrix} 0.639098 & 0.240602 & 0.097744 & 0.022556 \\ 0.453488 & 0.261628 & 0.191860 & 0.093024 \\ 0.452174 & 0.252174 & 0.234783 & 0.060869 \\ 0.325581 & 0.069767 & 0.348837 & 0.255815 \end{pmatrix} \quad (2)$$

Using the C-K equation, we can get:

$$P^{(n)} = P^n = \underbrace{P \cdot P \cdot \dots \cdot P}_n \quad (3)$$

Finally, the limit distribution of the transition probability matrix can be calculated as:

$$\lim_{n \rightarrow \infty} P^{(n)} = (0.547319 \quad 0.237316 \quad 0.15633 \quad 0.05904) \quad (4)$$

We conducted invariant measure test on the result:

Suppose: $\pi = (\pi_1, \pi_2, \pi_3, \pi_4)$

$$\sum_i \pi_i P_{ij} = \pi_j, \pi_j \geq 0, \sum_i \pi_i = 1 \quad (5)$$

Get the invariant measure for (0.547427, 0.238018, 0.15603, 0.058352), because of the limitation of precise stable distribution and constant error has some error, but all in the range of allowable error.

According to the above results, Markov chain, based on the previous weather in region A, concludes that the probability of precipitation in the future day is 54.743% in the interval (0, 200] 23.8% in the interval (200, 400] 15.63% in the interval (400, 800] and 5.9% in the interval (800, 1200] (the units of precipitation above are mm). Because the region A we chose belongs to the temperate continental climate, which is dry and rarely rains all year round, it is very rare for the precipitation to be greater than 1200mm. This is a low probability event, so we're not going to think about it.

4. Study on the Adaptability of Species Quantity and Type of Plant Communities to Drought Based on Differential Dynamics

4.1. Research Ideas.

Here we look for twelve plants that are typical of dry regions (see in Table 2), numbered 1 to 12. We categorize the plants into herbaceous plants from 1 to 6, bush plants from 7 and 9, and arbors from 10 and 12. The initial density of plant No. 1 was 120 plants /hm², No. 2 was 200 plants /hm², No. 3 was 160 plants /hm², No. 4 was 150 plants /hm², No. 5 was 165 plants /hm² and No. 6 was 135 plants /hm². The initial density of plants from 7 to 12 can also be seen from the table above. The area density of herbaceous plants is higher than that of bush plants, and bush plants are higher than that of arbors.

Table 3. Plant data sample

Number	Botanical name	Plant classification	Initial density (plant /hm ²)
1	Eurya nitida Korthals	Herb	120
2	Artemisia argyi Levl. et Van	Herb	200
3	Astragalus membranaceus (Fisch.) Bunge	Herb	160
4	Medicago L.	Herb	150
5	Pennisetum sinense Roxb	Herb	165
6	Trifolium repens L.	Herb	135
7	Rhododendron ovatum (Lindl.) Planch. ex Maxim	Bush	16
8	Albizia kalkora (Roxb.) Prain	Bush	8
9	Calligonum rubicundum Bge.	Bush	10
10	Pistacia chinensis Bunge	Arbor	7
11	Pinus thunbergii Parl.	Arbor	5
12	Liquidambar formosana Hance	Arbor	8

4.2. Research Method

Differential dynamics models are suitable for solving dynamic mathematical models. The result is simple and clear, and the result is clearer when combined with the image. This model plays an important role in this paper. When we think about the development of plant communities, we consider the interspecific relationships between them. According to the literature, the influencing factors, maximum growth rate and environmental capacity among different species all have certain effects on the number of plant communities. We model the differential equation as follows formula (6)-(8).

$$\frac{dx_i(t)}{dt} = r_i(t) \cdot x_i(t) \left(1 - \frac{x_i(t)}{N_i} - \sum_k a_k \frac{x_k(t)}{N_k}\right) \quad (6)$$

$$r_i(t) = \frac{L_i(t)}{1 + e^{-(h(t) - \bar{h})}} - \frac{L_i(t)}{2} \quad (7)$$

$$N(t) = \sum_i x_i(t) \quad (8)$$

Where $x_i(t)$ represents the number of species i ; $r_i(t)$ represents the growth rate of species i ; $L_i(t)$ represents the maximum growth rate of species i ; The above variables all take t as the independent variable. N_i represents the environmental capacity of species i ; a_k represents the influence factor of species k on species i ; $h(t)$ represents the precipitation at time t ; \bar{h} represents the average precipitation in the study area; $N(t)$ represents the total number of plant community species at time t .

4.3. Result Analysis

(1) Analysis of Impact Factors. Impact Factor Analysis for System (6):

First: $x_i(t)$

Under the condition that other factors remain unchanged, the right side of the equation of system (6) forms a quadratic function of one variable, which becomes

$$r_i(t) \cdot \left(1 - \frac{2x_i(t)}{N_i} - \sum_k a_k \frac{x_k(t)}{N_k}\right)$$

after derivative, and the extreme point is found to be $x_i^* = N_i \left(1 - \sum_k a_k \frac{x_k(t)}{N_k}\right) / 2$.

When $x_i < x_i^*$, $\frac{dx_i(t)}{dt}$ also increases with the increase of

x_i ; At $x_i > x_i^*$, as x_i goes up, $\frac{dx_i(t)}{dt}$ goes up. This is

realistic logic. When the initial number of species is small, there is no great limit to species growth under the existing resources. When the number of species is large enough, there are fewer resources and the growth rate is slow.

Second: $r_i(t)$

As $r_i(t)$ increases, $\frac{dx_i(t)}{dt}$ also increases, assuming other

factors remain constant. As the growth rate increases, so does the number of plants.

Third: N_i

If other factors remain unchanged, $\frac{dx_i(t)}{dt}$ increases with

the increase of N_i . Conversely, $\frac{dx_i(t)}{dt}$ goes down. The

growth rate increases as environmental capacity increases and material resources become more abundant.

Fourth: a_k

If other factors are kept constant, $\frac{dx_i(t)}{dt}$ decreases with

the increase of a_k ; Conversely, $\frac{dx_i(t)}{dt}$ increases. The

increase of plant influence factor will inhibit other plants, resulting in a decrease in their growth rate.

Fifth: $x_k(t)$

If other factors remain unchanged, $\frac{dx_i(t)}{dt}$ decreases as

$x_k(t)$ increases; Conversely, $\frac{dx_i(t)}{dt}$ increases. The number

of other species increases, resulting in less space for this species.

Impact factor analysis for system (7):

First: $L_i(t)$

Other factors remain unchanged. $r_i(t)$ increases with the increase of $L_i(t)$, and system (7) has an upper limit, that is, it does not increase infinitely with the increase of $L_i(t)$, but keeps $r_i(t)$ close to $L_i(t)$.

Second: $h(t)$

As $h(t)$ keeps increasing, $e^{-(h(t) - \bar{h})}$ keeps decreasing until it goes down to 0. And $r_i(t)$ keeps increasing until it reaches the upper limit.

(2) Pseudocode Flowchart.

Combining the previous model with the model of this differential equation, we get the process of species number change over time as Table 4.

Table 4. Algorithms of the process of species number change over time.

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Input:  $N_i, L_i(t), a_k$  ( $i, k=1, \dots, n$ ),  $\bar{h}$ 
Output:  $x_i(t)$ 
for  $t = 1$  to 100 do
    According to equation (4), we get  $h(t)$ 
    According to  $h(t)$  and equation (7), we get  $r_i(t)$ 
    The number of species at time  $t$  can be calculated according to  $r_i(t)$ 
end

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(3) Solution to Precipitation and the Number of Plants Change over Time

To describe the good and bad of a plant community, we need to look at the growth of its species. The selected plant community contains six species, namely three herbs, two bushes and one arbor, and the initial value given is (54, 42, 45, 17, 16, 4). Forecast the future growth trend under irregular weather changes on an annual cycle. By studying the weather data for Region A from February 2020 to February 2022, we use Markov chain to predict the future precipitation. The results of (4) are used to simulate random precipitation in the next few years, as shown in Figure 4. With the change of time, the number of different plants is also changing with time as shown in Figure 5.

Double y axes are used in the diagram. Only the right y

axis is used for arbors, and the left y axis is used for other plants. This is true for all of the following cases with double y axes. Based on the above two figures, it can be seen that plant changes are affected by precipitation and have a certain after-effect. Further study showed that when the precipitation changed, the trend of herbs changed obviously, followed by bushes and arbors. This reflects the drought resistance: arbors > bushes > herbs. The influence factors between species are also considered in the differential equation. Most plants compete with each other in the natural environment. By analyzing the data, we calculated the impact factor and reflected it on the image. According to the image, it can also be concluded that the plant community can survive and finally reach A steady state under the irregular weather in region A.

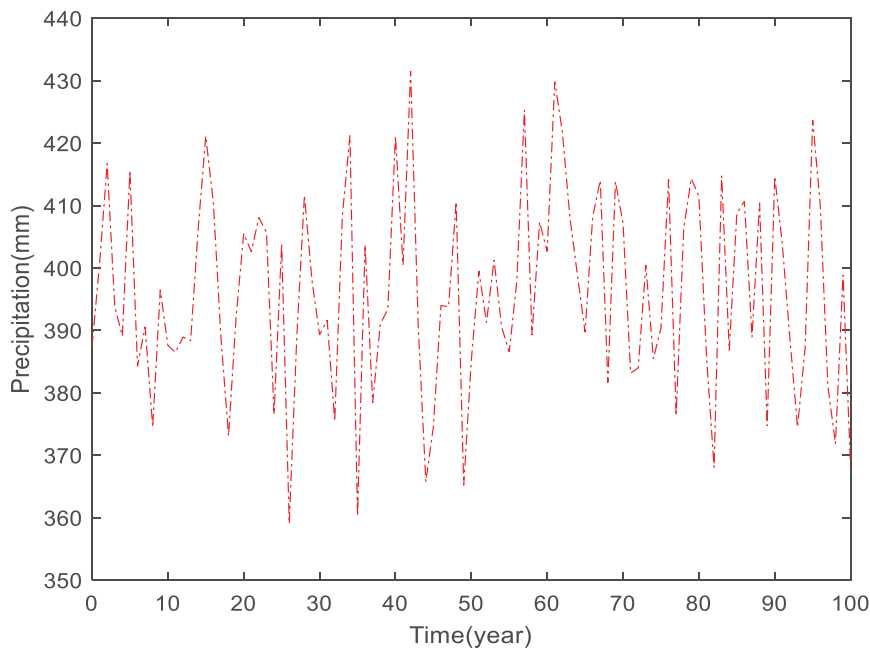


Figure 4. Plot of future precipitation over time.

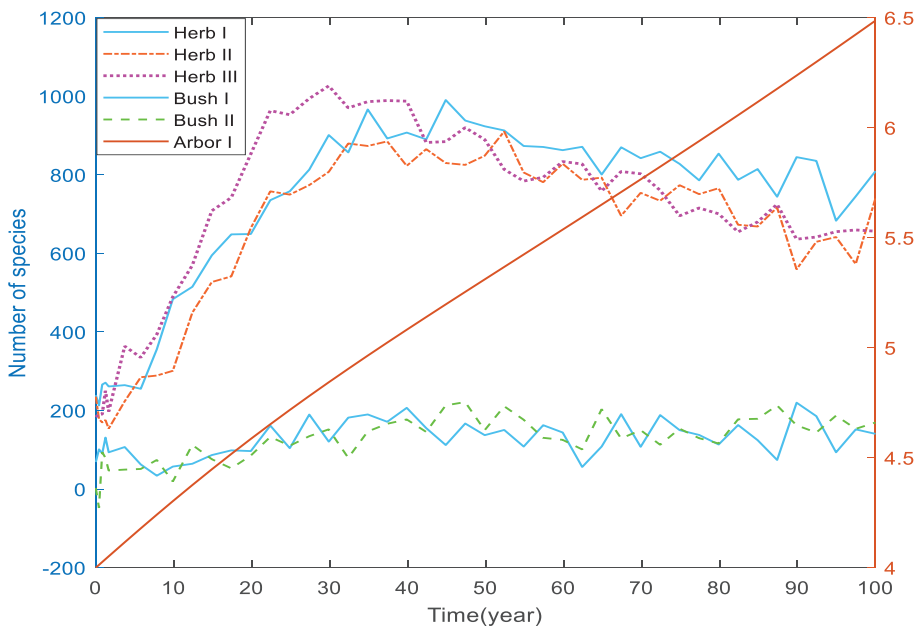


Figure 5. The number of future plant species over time.

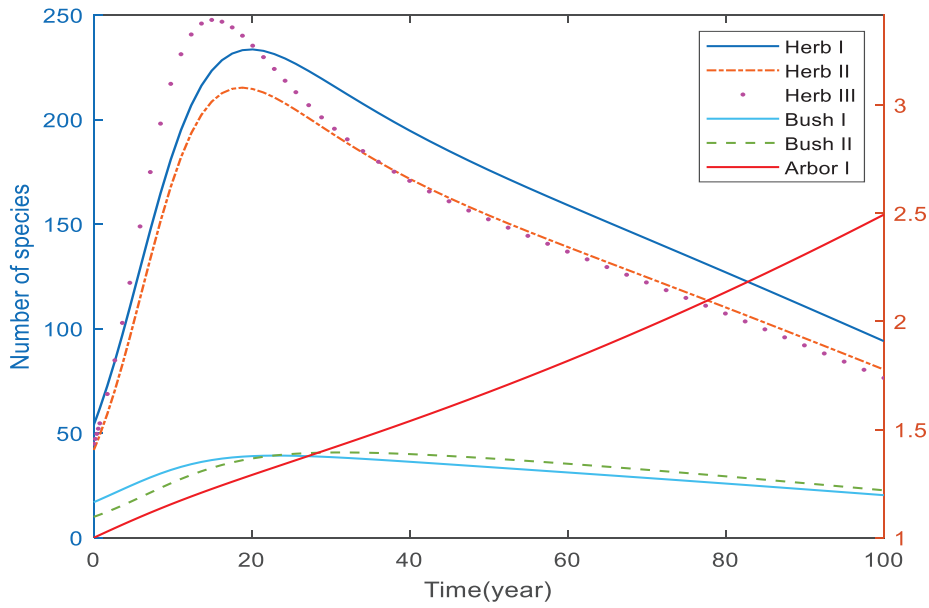


Figure 6. A plot of the number of species over time under extreme drought conditions.

(4) Solution to Extreme Drought Conditions.

The differential dynamics model considers the influence factors between plants and environmental capacity. Simply changing the amount of precipitation can simulate the weather and draw the desired conclusions. In order to simulate a more arid environment, we will calculate the probability of precipitation in the interval (0, 200] as 68%, the probability of precipitation in the interval (200, 400] as 23%, the probability of precipitation in the interval (400, 800] as 6%, and the probability of precipitation in the interval (800, 1000] as 3% (all the above precipitation units are mm) according to the existing conclusions to get Figure 6.

As can be seen from Figure 6, under extreme drought conditions, plant communities gradually die over time. Soil in ecological environments can dry out and crack due to lack of

water. The land will desert. In order to protect the environment, human intervention is needed, such as artificial rainfall and afforestation to restore the activity of plant community.

(5) Optimal Number of Species.

The number of species also affects the rate of species growth in a plant community. A single species population, disturbed by small environmental factors, will degrade. When the complex plant community meets the interference of environmental factors, it can self-regulate and achieve stability again. Therefore, we discussed the relationship between the total number of plant communities with different species and changes over time, and drew the cases of 3,4, and 5 species respectively, as shown in Figure 7.



Figure 7. Bubble map of number of plant species

According to Figure 7, when the number of species is 3, the number of plant community will first increase, then decrease, and finally disappear gradually. When the number of species is 4 or 5, the number of plant communities gradually increases and becomes stable. So it's reasonable to assume that plant populations benefit when the number of species is at least four.

5. Analysis of the Species of Plants

5.1. Proportional Combination of Different Plant Species

Based on the above analysis, we first control 6 different

species, and respectively adjust the different ratios of herbs, bushes and arbors as (herbs, bushes, arbors). Using biological knowledge, six different combinations of (6,0,0), (4,2,0), (3,2,1), (3,3,0), (3,0,3) and (2,3,1) are selected. When other conditions are suitable, the relationship between the number of plants over time is drawn respectively, which provides a reference for the development of subsequent plant communities.

5.2. Adaptation of Different Plant Species

Below is a graph of trends in six plant communities over time, ranked from largest to smallest in terms of the number of herbs. The Figure 8 analyzes the similarities and differences in the future due to the differences in plant populations.

For (a): The six herbaceous plants were generally competitive in their growth over time. At the beginning, the living environment is favorable and the competition for resources is not fierce. With the increase of time, the environmental capacity gradually reached saturation, and the growth curve of various plants became "S" shape, and the "inferior" plants gradually died. Although the number of plants has been at a high level, but the ability to tolerate drought is weak.

For (b): Four herbs and two bushes, according to the image analysis, the growth rate of herbs is obviously higher than that of bushes, which is obviously caused by different families. Since bushes have taller plants than herbs, the influence on herbs is great. Compared with figure (a), it can also be seen that the growth rate of herbs is slower. In the long growth cycle, it is difficult to form a strong drought tolerance system.

For (c): The combination of three herbs, two bushes and one arbor, the double Y-axis is adopted in the image, so that the trend changes can be more clearly seen. Because compared to herbs, the growth rate of arbors is very small. This combination is more common in nature and also

represents the vertical community of plant communities. With the change of time, the whole plant community tends to be more balanced and has strong tolerance to drought, which is an ideal species combination.

For (d): The combination of three herbs and three bushes generally reflects the changes in the initial stage of the plant community, and bushes have more influence on herbs. Because bushes are relatively dense and abundant, they are more effective in inhibiting herbs. When there is a small increase in the number of bushes, the trend of herb growth is curbed. The growth cycle of bushes is much smaller than that of herbs, but it can also be seen that the growth rate is gradually increasing. After long-term development, it is not conducive to the formation of stable plant communities, and the adaptability to drought is relatively weak.

For (e): A combination of three herbs and three arbors does not easily form this type of community in a normal plant community. With the increase of time, herbaceous plants declined significantly. However, the growth rate of arbors is very low, unable to reach a stable equilibrium state, the ability to adapt to drought is not strong, if there is a big drought will become barren.

For (f): A combination of two herbs, three bushes, and one arbor, this community corresponds to the distribution of plants in nature. As you can see from the image, the growth rate of herbs is very fast at the beginning. When the number of bushes and arbors came up, there was a phenomenon of decreasing first and then leveling off, reaching a relatively stable state, with strong drought tolerance. Over time, this plant community is better able to evolve into a plant community with higher species richness.

To sum up: we believe that the top three drought tolerance are figure(c)>figure(f)> figure(d). Suitable species types have better resistance to drought and can form relatively stable plant communities.

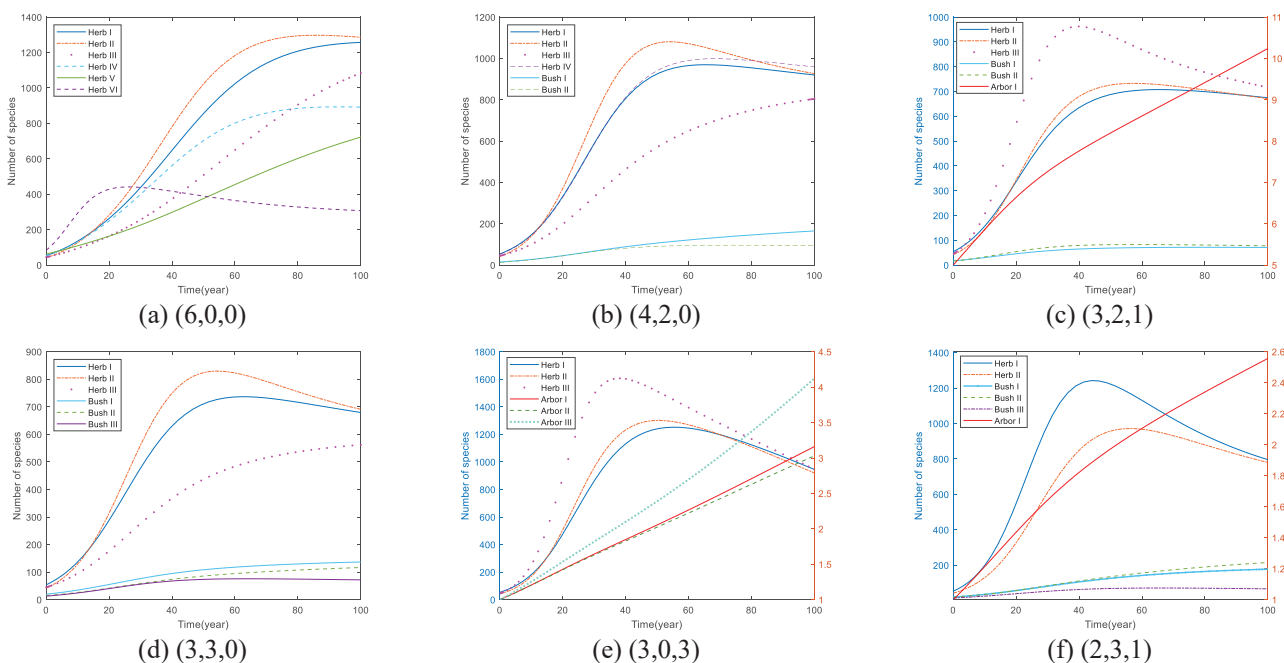


Figure 8. The combination of different plant species

6. Sensitivity Analysis

In plant communities, there are many other factors that

affect plant growth in addition to those we have already discussed. The effect of pollution on plants in real life cannot be ignored. In recent years, many plant communities have

been seriously degraded due to environmental pollution [8]. Therefore, we further expand the original differential equation and add pollution disturbance factor v to get:

$$\frac{dx_i(t)}{dt} = r_i(t) \cdot x_i(t) \left(1 - \frac{x_i(t)}{N_i}\right) - \sum_k a_k \frac{x_k(t)}{N_k} - vx_i(t) \quad (9)$$

We still chose a combination of three herbs, two bushes and one arbor. According to the above analysis, this combination is the best drought resistance combination. This combination was selected for sensitivity analysis, and the disturbance factors of environmental pollution were selected as 0,0.1,0.2,0.3,0.4, and 0.5, respectively, to obtain the changes of the number of different species over time as shown in Figure 9.

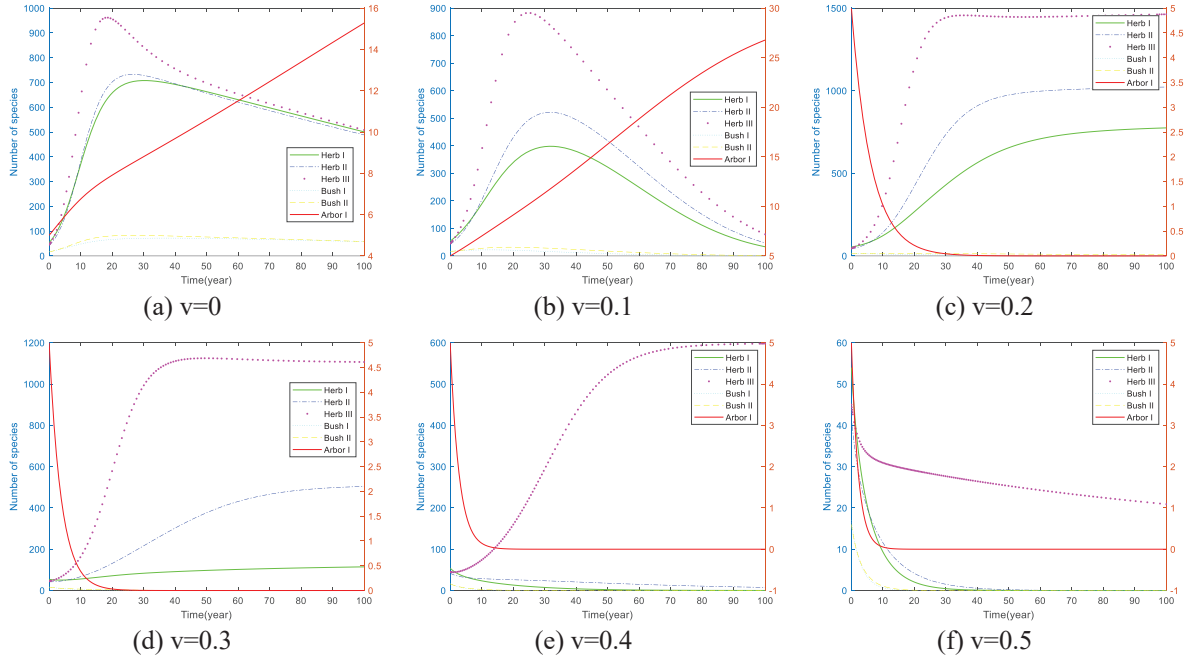


Figure 9. Graphs of the number of different species over time under disturbed conditions.

With the continuous increase of v , that is, the increasing of environmental pollution, the first two kinds of bushes showed a downward trend, followed by arbors and herbs. The result is food for thought. In this plant community, due to the initial number of herbs, so when the pollution is not serious, it can be increased to a certain extent. But as the number of bushes and arbors dwindled, the herbs began to suffer, too, diminishing. When $v=0.4$, two of the three herbs declined from the beginning, indicating that Herb I had significantly stronger pollution resistance than the other two herbs. When environmental pollution is already very severe, the result is

that all plants begin to die. From the above analysis, we can see that environmental protection should be strengthened. As can be seen from the above picture, as long as the environment is polluted, the plant community will definitely be affected. If the pollution is severe, then the plant community will be seriously degraded. In addition to establishing changes in the number of species at different levels of pollution, the total number of species in a plant community is often a good indicator of plant community transformation.

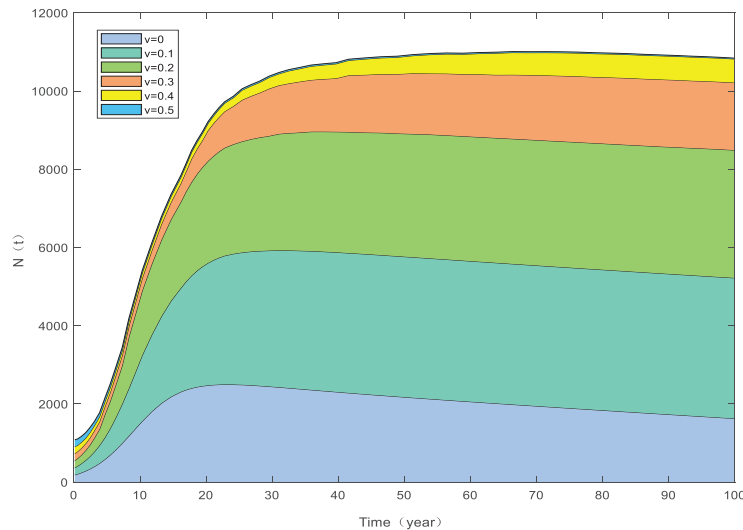


Figure 10. Area stacking diagram of the total number of species over time under disturbed conditions.

According to the figure 10, when the environment is pollution-free, the total number of plant communities increases first and then decreases, which conforms to the rule. However, when the pollution degree increases, the number of species in the plant community decreases sharply to 0, which is the same as the above analysis result.

7. Conclusion

In nature, plant community is the carrier of species and brings together all kinds of biological resources. It is the main body that provides the function of ecosystem and the comprehensive index of the basic property of land. It provides a favorable environment for human existence. In this paper, we established two models for region A, Markov chain and differential dynamics model, which were used to solve the future weather prediction and species number change respectively. Because have no aftereffect of Markov chain, has inherent advantages in forecasting the weather, finally the limiting distribution of transition probability matrix is (0.547427, 0.238018, 0.15603, 0.058352), for the further study of plant community succession process played an important role in guiding. Through the establishment of differential dynamics model, we simulated the changes of plant community over time, and obtained the relationship between the changes of plant community and precipitation, environmental capacity, maximum growth rate and influencing factors. Figure 6 is also drawn to intuitively show the changing trend of the number of species. Further analysis showed that under the more extensive drought conditions, even though the plant community reached the optimal combination, it could not reach equilibrium and finally degraded. Through the analysis of the number of species, we obtained that the number of species in the plant community should not be less than 4 to have a positive effect. Plant communities of less than 4 species will gradually degrade when disturbed by nature.

We also studied the combination of different species and analyzed the drought resistance of plant communities. Six common combinations in nature were selected, which showed different development trends over time under the same conditions, and three herbs, two shrubs and one tree had stronger drought resistance. This suggests that species diversity affects resistance. When considering environmental pollution, the disturbance factor is introduced to get the change of species number. When the environmental pollution is light, it has little impact on the environment, and the plant community can purify itself through recycling. However, when the pollution is very serious, the plant community will become dysfunctional and degenerate as a whole.

The evolution of plant community is the historical evolution process of plant community, which is the change of geological time and corresponding climate change. The evolution of plant community is mutually restricted with the evolution of plant species and is also carried out in conjunction with the evolution of animal kingdom. The type

of modern plant community is the product of the development of nature history, and is unique to the development of nature at present stage. In order to protect the plant community through the study of this paper, we should: (1)Regulate the type and number of species in the plant community to form a stable plant community. (2)Control precipitation to meet the needs of plant community, not too little or too much. (3)Set up nature reserves to prevent man-made destruction of plant communities.

8. Data Availability

The data in this paper come from Question A of the 2023 American College Students Mathematical Modeling Competition.

9. Conflicts of Interest

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

References

- [1] Cen Yang, Jinghui Peng, Xiya Hu. "The ability of plant communities to regulate microclimate comfort and its influencing factors: A case study of the park green space in Huaihua City, Hunan Province". *Journal of Central South Forestry University of Science and Technology*, vol.42, no.12, pp.183-191, 2022.
- [2] Dongdong Du. "An Effects of drought and its soil residual effects on the growth of typical grassland plants on the Loess Plateau". *Lanzhou University*, 2022.
- [3] Yulin Huang, Weicong Fu, Jingru Chen. "Study on the impact of plant community characteristics on the microclimate of summer park shade space". *Chinese Landscape Architecture*, vol.38, no.3, pp.118-123, 2022.
- [4] Liangliang Zhang, Yongzhen Wang. "The impact of garden plant communities on summer microclimate characteristics". *Journal of Luohe Vocational and Technical College*, vol.17, no.2, pp.17-22, 2018.
- [5] Ekundayo O Y, Abiodun B J, Kalumba A M. "Global quantitative and qualitative assessment of drought research from 1861 to 2019". *International Journal of Disaster Risk Reduction*, 2022: 102770.
- [6] Chelmeg L I U, HE Y, SUN S, et al. "Responses of herbaceous community characteristics to short-term precipitation changes in semi-arid sandy land". *Acta Prataculturae Sinica*, vol.29, no.4, pp.19, 2020.
- [7] Yin Wang, Jianming Wang, Mengjun Qu, et al. "Plant community construction in arid in land river basin and its key driving factors". *Biodiversity Science*, vol.30, no.2, ID21419 2022.
- [8] M. M. Varughese, L. P. Fatti. "Incorporating environmental stochasticity within a biological population model". *Theoretical Population Biology*, vol.74, no.1, pp. 115-129, 2008.