

Study on the relationship between plant diversity and drought cycle based on mechanism models

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Abstract. The number of species plays an important role in adapting plant communities to successive drought cycles. This paper, taking the number of plant communities and populations as the research object, simulates the change process of plant population to understand the importance of plant species diversity through the interaction between plants and the impact of a drought environment. Before the experiment, a prediction model was established a prediction model to simulate the change of plant population number according to the mechanism of the change of plant population number, combined with the logistic model, and inserted it into the prediction model by considering the change of drought cycle. It describes the fluctuation of plant population, the competition and help between plant populations. By setting the criteria for judging the benefits to the community, it was assumed that the impact factors of a single species obeyed uniform distribution, carried out a large number of data simulation, studied the impact factor distribution of a single to diversified plant population, and found that with the increase of plant population, the whole plant community would tend to be stable, and the whole ecosystem would also benefit. It also shows the importance of rich plant populations. Then, this paper took into account the influence of different plant types, and carried out single simulation and combination simulation respectively for the two types of plants. Also, through a large number of data simulation, this paper obtained the curve of the impact factors changing with the population number. After analysis, it was found that the multi-population combination of multi-type plants is necessary for the stability of the ecosystem.

Keywords: mechanism model, population variation, multiple environments.

1. Introduction

In ecosystems, different species of plants respond differently to stress. For example, the frequency and severity of drought differ in other regions, and the number of species plays a crucial role in adapting plant communities to successive generations of drought, including competition and mutual support among plants [1]. Zhao Yudong [2] and Lu F S [3] pointed out in the Regulation of Plant Diversity on Soil fungal community response to drought and plant Invasion that drought and plant richness both significantly affected plant community productivity.

The Relationship between plant diversity in Alpin Grassland and the Stability of Godron Community and its Environmental Driving Factors [4] proposed that soil nutrients had an important effect on the distribution of species evenness. The smaller the fluctuation of community composition species, the less the sum of community variances [5], thus reducing the community volatility and making the community more stable [6]. Studies have shown that dominant species are more stable than other species [7], and the increase of dominance of dominant species will make the plant community more stable [8].

Precipitation can promote seed germination in soil, accelerate the dissolution and flow of soil available nutrients, improve plant nutrient absorption efficiency [9], improve species diversity and thus improve community stability [10].

2. A mechanistic model for predicting population size

In this part, we apply the mechanism model and use the differential equation method to make the prediction.

2.1. Model description

We're going to describe populations in terms of levels of species diversity, three levels of species.

$$\left\{ \begin{array}{l} \text{level 1 [1,3]} \\ \text{level 2 [4,6]} \\ \dots \\ \text{level 10 [28,30]} \end{array} \right. \quad (1)$$

We set the population growth rate under normal conditions as the base growth rate, and set helpful influence factors and competitive influence factors.

r is the growth rate of population

r_{basic} is base population growth rate

δ is factors affecting population growth rate

$$r = r_{basic} + \delta \quad (2)$$

We assume that the population depends on the dryness of the climate and the relationship between species, and the dryness is replaced by the amount of precipitation at a given time.

P is Precipitation

α_i are factors influencing the number of helpful communities

β_j are factors influencing the number of competitive communities

N is total number of species

N_{max} is maximum number of species the environment can accommodate

λ is drought tolerance of plant communities

$$\delta = \frac{P}{\lambda} + \sum_{i=1}^m \alpha_i \frac{N_i}{N_{max}} - \sum_{j=1}^n \beta_j \frac{N_j}{N_{max}} \quad (3)$$

From these two formulas, we can get an ordinary differential equation.

r is the growth rate of the population

u is Number of each species present (fixed)

$$\frac{dN}{dt} = r \left(1 - \frac{N_u}{N_{max}u} \right) N \quad (4)$$

2.2. Simulation

Under the assumption that the external conditions remain unchanged, we assign specific values to the above model and obtain the simulation curves of the total number of plants and the level of plant diversity.

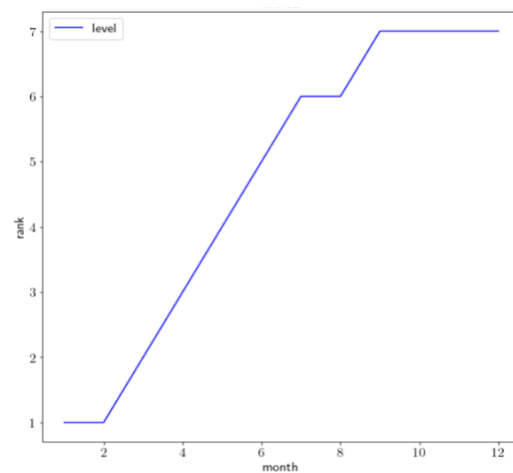
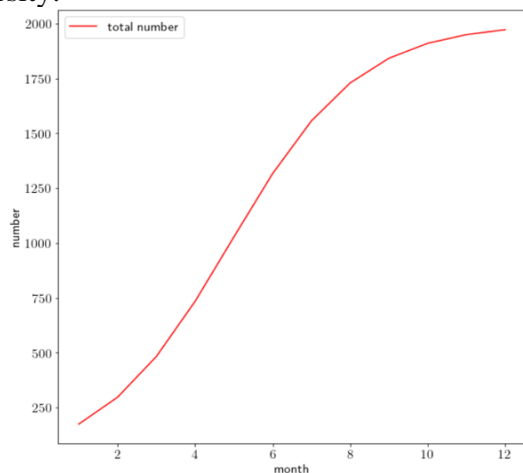


Figure 1: Trends in species quantity changes **Figure 2:** Trends in changes in species quantity levels

In non arid environments, both the total number of plants and the level of plant population show a rapid and then slow growth.

This is followed by a negative impact factor under drought conditions.

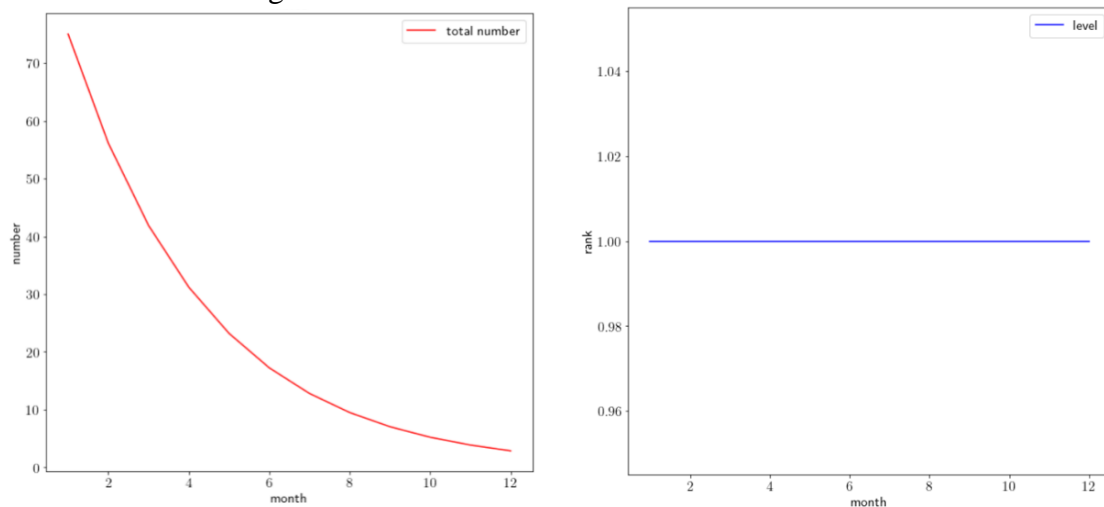


Figure 3: Trends in species quantity changes **Figure 4:** Trends in changes in species quantity levels

In arid environments, the total number of plants continues to decline, and the level of plant population remains at its lowest level.

2.3. Community the number of species needed to benefit and the impact of increased diversity

In this part, we use the uniform random partial summation model to fit the influencing factors of individual plant species and the influencing factors of multiple plant interactions.

2.3.1 Community how to benefit

In order to simplify the income model, we assume that the influence factors of different number of plant populations meet the uniform distribution of $[-1, 1]$ and x_i ($i=1, 2, \dots, 20$) represents the number of plant populations in the sample. Here, the impact factor refers to the number of species in the plant population as a reference, and the richness of a single species is 1. With the continuous expansion of the richness, the scatter diagram of the change of the impact factor caused by other organisms is shown in the figure (5) below.

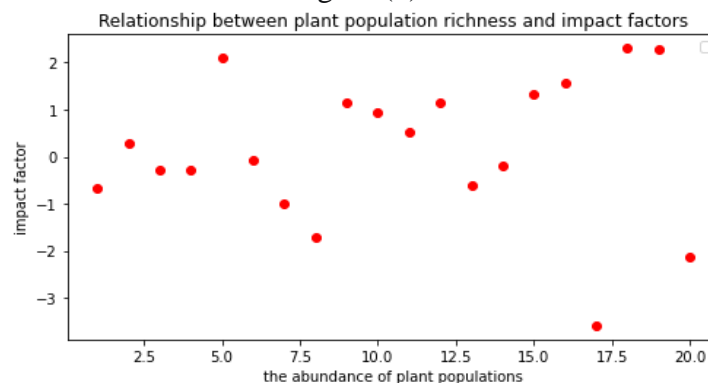


Figure 5: Relationship between plant population richness and impact factors

We can see that the influencing factors are randomly distributed across various ranges and the value fluctuates around 0.

We will determine whether it benefits the community based on the amount of photosynthetic output per unit of time. For example, assume that the monthly output of a plant is 500g, bring this data into the model established in the first question, and specify the output of the whole community when the impact factor is 0 as the standard yield. If the output is higher than this, it benefits the community.

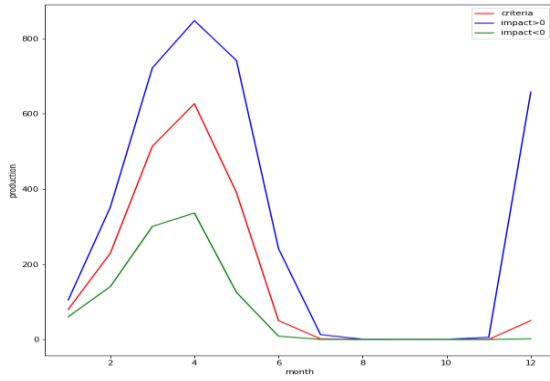


Figure 6: Photosynthetic yield during non drought conditions

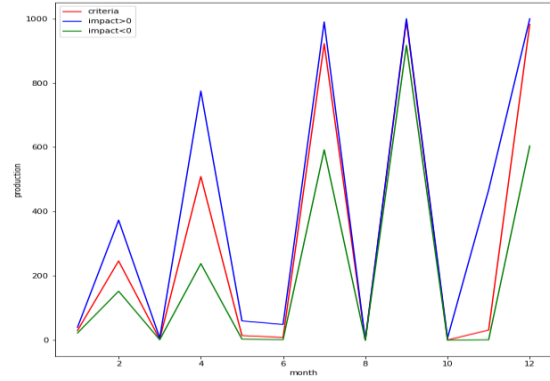


Figure 7: Photosynthetic yield during drought conditions

The figure left shows the situation of a less severe drought, and the figure right shows the case of a more severe drought.

2.3.2 The effects of increasing plant population

In order to ensure the universality of the experiment, when the number of plant populations was 5, 10, 15, and 20, the impact factors were fitted many times as the impact factors of each experiment.

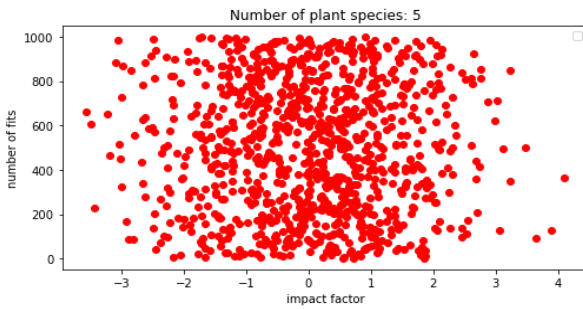


Figure 8: The impact of five plants on influencing factors

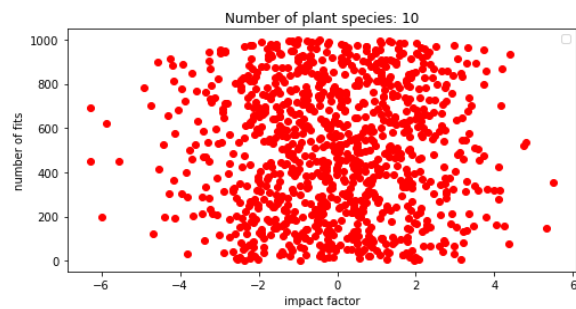


Figure 9: The impact of ten plants on influencing factors

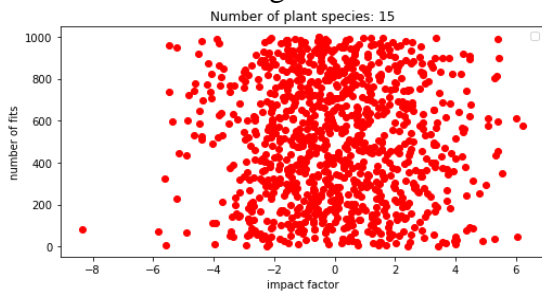


Figure 10: The impact of fifteen plants on influencing factors

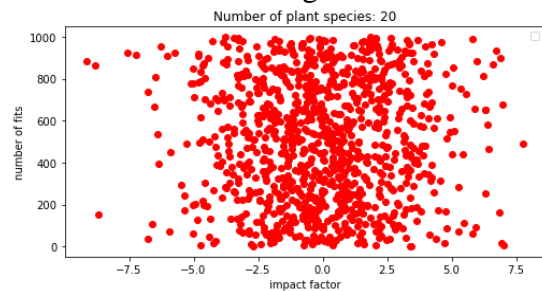


Figure 11: The impact of twenty plants on influencing factors

2.4. Analysis of effects on arboreal plant and herbaceous plants

According to the above ideas, we can infer the impact of the influencing factors on the plant community when the species community is relatively simple. For example, taking herbs and tree plants as examples, the above factors can be used as the influencing factors of herbs or tree plants. We can adjust the reference of herbs and tree plants at the same base level. We assume that the influence factors of herbaceous plants in the community meet the uniform distribution of $[-0.5, 0.5]$, and that of arboreal plants in the community meet the uniform distribution of $[-1, 1]$. By integrating the mean values of the influence factors of the two many times, the influence factors of herbaceous plants and arboreal plants are studied separately to ensure the universality of the fitting. Then, through the mean fitting of the two impact factors, the impact

on the overall community was studied. We concluded that, under the condition that the ecological environment could withstand, the impact factors on the general ecology gradually increased with the increasing richness of the species community. The specific experimental fitting is shown in the table below.

Table.1. Impact Factor Analysis

Plant species	Number of experiments	Community number
Herb	10000	[0,21]
Arboreal plant	10000	[0,21]
Herbs interact with tree plants	10000	[0,21]

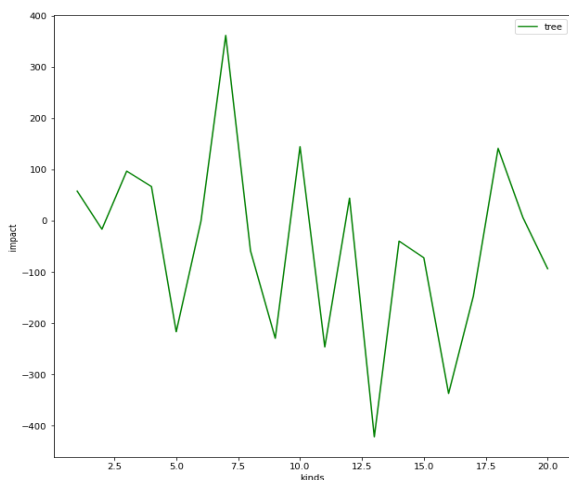


Figure 12: Impact factors for the tree species

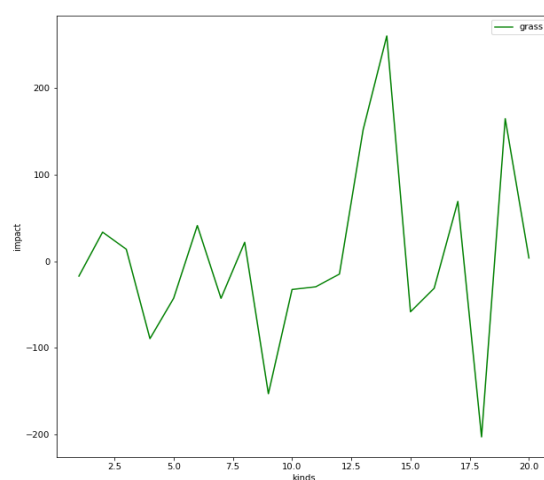


Figure 13: Impact factors for the herb species

The figure on the left is the sum of the impact factors after 10,000 simulated trials for the tree species from 1 to 21, and the figure on the right is the sum of the impact factors after 10,000 simulated trials for the herb species.

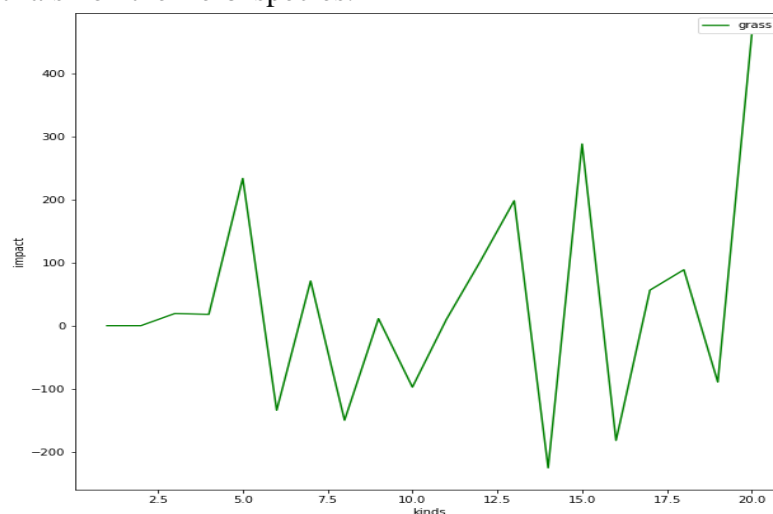


Figure 14: Impact factors for the tree and herb species

After combining two kinds of plants, the fluctuation range is smaller than that of a single kind of plant.

3. Results

From figure1 and figure2, it can be concluded that when the influence factor is positive, the total number of plants and the diversity level will increase firstly, then become full and finally tend to balance.

From figure3 to figure4, it can be found that under drought conditions, the number of plants decreased at a faster rate, and the level of diversity remained at the lowest level.

From figure5 to figure7, it can be clearly seen that when the impact factor is greater than 0, the total yield is always above the standard yield, and when the impact factor is less than 0, the total yield is always below the standard yield. By analyzing the scatter plot above, when the number of species is higher than 9, The influence factor is greater than 0 in many cases.

From figure8 to figure11, it can be seen that under the increasing abundance of plant population and with the increase of experiment times, the influence factors of plant community gradually tend to 0. Therefore, with the rise in the number of species, the whole ecosystem will become more and more stable. When the number of species is small, plant communities may increase rapidly due to the more prominent influencing factors. When the number rises to a certain extent, it may become stable because of the smaller influencing factors, resulting in the decline of the plant population. Therefore, the high number of species in an ecosystem guarantees ecosystem stability.

Through the settings in Table 1 Impact Factor Analysis, the influence factors of different combinations and quantities of plants were examined. And figure 12 and 13 were formed.

From figure12 to figure13, it can be found that the fluctuation range of influence factors of herbaceous plants is obviously smaller than that of arboreal plants.

From figure14, by randomly combining herbs and tree plants, we found that their fluctuation range was between pure herb combination and pure tree plant combination. Therefore, pure herb combination was selected if stability was pursued, while pure tree combination was selected if possible high impact factors were pursued. Generally, both combinations were selected, and the number of both remained similar.

4. Conclusions

In this paper, the changes in plant population under drought conditions were analyzed in detail, as well as the effects of factors affecting plant population on adaptation to drought and on plant population itself with the continuous expansion of plant population richness. We first established a model that considered the interaction between different plant populations in the drought cycle to predict the changes in the number of plants and population of a plant community in the cycle. We found that the number of plants decreased quickly under drought conditions, and the diversity level was kept at the lowest level. Then, we introduced the conditions under which the plant population could benefit. In addition, the minimum number of species required by the plant community is studied, and the combination of different types of plant species is explored through sensitivity analysis. It is found that under the condition that the ecological environment can withstand the increasing richness of the species community, the influence factors on the overall ecology are gradually enhanced. Then the phase of the drought factor in the model is changed to change the drought frequency. we obtained the conditions to ensure the long-term survival of plants, that is, firstly, to ensure that the plant community is placed in an environment with sufficient precipitation; secondly, when the plant population increases, the benefits to the plant community will also increase; at the same time, when the number of plant population is large enough, the whole community will tend to be stable, so it is necessary to increase the number of initial populations as much as possible. At the same time, plant types should be grown as far as possible to ensure population quantity.

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