Problem Chosen	2021	Team Control Number
A	**MCM/ICM Summary Sheet**	**2103226**

Fungi, Homeostasis and Biodiversity

Summary

The carbon cycle is one of the most important chemical cycles on earth, and fungi are important participants in the earths carbon cycle. Certain fungi play an important role in the decomposition of wood fiber, and the decomposition rate is related to the growth rate of the fungus and the moisture resistance of the fungus. We mainly studied the interaction of several main fungi in symbiosis under various environmental conditions, and its influence on the rate of decomposition of lignocellulose. In the research process, we focused on two factors, the growth rate of the fungus and the moisture resistance of the fungus. When considering the temperature factor, we assumed that its change is not continuous, and conducted a sub-gradient study.

First, we selected five common lignocellulosic fungi as the research objects. By constructing a population competition model for a variety of fungi groups, the initial number of each fungus, growth rate, humidity resistance, temperature, humidity and other variables are used as input, and the output of the decomposition rate of the decomposition product is obtained.

Second, because environmental conditions affect the growth rate of fungi, which in turn affects the interaction between different fungi. We have performed linear regression modeling on the interaction strength between different species of fungi. By introducing different environmental conditions, we can predict the interaction between fungi, and vice versa. Through this method, we brought in the characteristic environmental condition values of different climates, and we predicted the advantages and disadvantages of various fungi in arid, temperate, rain forest and other climatic environments.

Third, we compared the decomposition rate of a single fungus under a variety of different environmental conditions with the decomposition rate of a combination of the same amount of fungi under different environmental conditions, and found that the latters decomposition rate was significantly higher than the former. At the same time, if the environmental conditions are changed quickly, the latter can better guarantee a certain decomposition rate. This shows that the interaction of multiple fungi plays a positive role in maintaining the stability of the ecological environment, and biodiversity is of great significance.

Keywords: Logistic Law; Differential equation;Neural Network;Biodiversity

Contents

1 Introduction

1.1 Background

Carbon cycle plays an important role in the earth, and it is an important part of the earth's life. The decomposition of organic materials is a key part of carbon cycle, in which one of the important links is the decomposition of plant material and woody fibers. Fungi play a key role in the global carbon cycle as the main decomposers of litter and wood. Although current climate models reflect limited functional variation in microbial groups, fungi differ vastly in their decomposing ability. [1]

Recently, some research articles have found the characters that determine the decomposition rate of fungi and the relationship between them by analyzing the decomposition of wood by fungi. For these traits, the growth rate and water tolerance of fungi are worthy of our attention and analysis. It is found that these two characteristics are related to the response of fungi to different environmental conditions and natural resources. We will analyze the decomposition of different fungi and the effect of the interaction between strains on the population decomposition, and predict the decomposition of wood by fungi in a large range through experimental data processing.

1.2 Restatement of the Problem

- **Task 1**: Build a model to decompose ground waste and wood fiber through a variety of fungal activities, which have different growth rates and different moisture resistance, and describe the interaction between different types.
- **Task 2**: Examine sensitivity to rapid environmental fluctuations and determine the overall impact of changing atmospheric trends.
- **Task 3**: Make predictions for different environments based on our models.
- **Task 4**: When the local environment changes, predict the importance and role of biodiversity.
- **Task 5**: Write a two-page result article in a college textbook.

1.3 Problem Analysis

To solve these problems, first of all, we need to establish a mathematical model to describe the decomposition of litter and woody fibers by fungal activities in the presence of multiple species of fungi. Here, we only focus on the effects of growth rate and humidity tolerance on the decomposition rate of fungi. When there is a single fungus, we establish the traditional logistic model to predict the change of population quantity and get the maximum carrying capacity of the stable population. For a variety of fungi, we use logistic competition model, considering the influence of temperature, humidity and other environmental conditions on their growth. Here, we mainly study and analyze the species of white rot fungi, brown rot fungi, soft rot fungi and other fungi. At the same time, we should also consider the short-term and long-term effects of the interaction between different strains of growth rate and humidity tolerance, and describe the change trend between them.

Then, we make specific prediction for different species and strains in different environments. For different environments of drought, semi-arid, temperate and tropical, we use a large number of data to calculate and fit, including the influence of time, temperature, humidity and other variables on the growth rate of fungi, and predict the growth rate and action intensity of fungi.

Finally, assume a locally variable simulation environment, which is to describe the impact of fungal community diversity on decomposition rate and efficiency. The decomposition amount calculated by data is compared, and obtain the importance of biodiversity.

2 Assumptions and Justifications

Our assumptions are listed below:

1. **The fungi in this article only breaks down ground litter and woody fibers.** Enzymes produced by fungi are often highly specific and difficult to decompose other biomass.
2. **The change of fungal number obeys Logistic Law.** The growth and reproduction of fungi are limited by natural resources and environmental conditions, it is impossible to grow without growth.
3. **The ecosystem we choose below is a steady state, and the number of various organisms is stable.** Most ecosystems are relatively stable, and periods of drastic changes account for a relatively low percentage.

3 Notation

Abbreviation	Description	Unit
K	The number of fungi populations in a given environment	-
t	Time	h
$x_i(t)$	The number of fungi i	-
r_{i0}	The fixed increasing rate of fungi i under the condition of abundant resources	%/h
r_i	Increasing' rate of fungi i	%/h
σ_{ij}	The biomass consumed per unit quantity fungi i is $\sigma_i j$ times that of fungi j	-
T	Temperature	°C
H	Humidity	%
v	Decomposition rate per unit fungus and per time	g/cfu·s

4 Competitive Model

4.1 Traditional Logistic Model

When there is only one kind of fungi in the environment, we use the single linear function to express the relationship between the number of fungus and the inherent growth rate r.

Meanwhile, the number of fungus is limited by natural sources and environmental conditions, i.e. if $x = K$, then increasing rate $r(K) = 0$ where K represents the maximum capacity of the number of fungi and obeys Logistic Law.

Thus, the relation between the number of fungi and time is

$$\begin{cases} \frac{dx}{dt} = r_0(1 - \frac{x}{K})x \\ x(t_0) = x_0 \end{cases} \tag{1}$$

x_0 is the number of fungi at first and t_0 is the time at first.

Solve (1) to get the number of fungi relationship, which is

$$x(t) = \frac{K}{1 + (\frac{K}{x_0} - 1)e^{-r_0(t-t_0)}} \tag{2}$$

We can conclude the following conclusions below:

1. $\lim\limits_{t\to\infty} = K$, which means that for $x_0 \neq 0$, the number of fungi will become K at last.
2. If $0 < x < K$, then $\frac{dx}{dt} = r_0(1 - \frac{x}{K})x > 0$, which means that the number of fungi is increasing.
3. Based on (1), we know that

$$\frac{d^2x}{dt^2} = r_0^2(1 - \frac{x}{K})(1 - \frac{2x}{x_m})x \tag{3}$$

Then we know that if $x < \frac{K}{2}$, then $\frac{d^2x}{dt^2} > 0$, the the increasing speed is increasing. If $x = \frac{K}{2}$, then the increasing speed is fastest. Then it drops and becomes zero until $x = K$.

4.2 Multi-Fungi Competitive Model

We will expand Traditional Logistic Model to Multi-Fungi Competitive Model. In this model, we will consider not only limits of natural sources and environmental conditions, but also the interactions with other fungi. Generally speaking, the interactions among different species are: competition, predator and prey, mutually beneficial. Predating ralationship mainly exists between the predator and the producer and between the predators. The mutually beneficial symbiosis generally exists between the decomposer and the producer such as rhizobia and legumes. Thus, for fungi as the decomposer we will mainly consider the competitive relationship.

In equation (1), $(1 - \frac{x}{K})$ presents because of the natural resources consumed by a kind of fungi causes the bloc king effect to fungi. Now we should consider resources consumed by other fungi.

When more fungi live in the environment, if we consider resources consumed by other fungi, we can subtract some items from $(1 - \frac{x}{K})$, which should be proportional to the number of other fungi. For fungi 1, the new equation is

$$\begin{cases} \frac{dx_1}{dt} = r_0(1 - \frac{x_1}{K_1} - \sum_{j=2}^{n} \sigma_{ij} \frac{x_j}{k_j})x_1 \\ x_1(t_0) = x_{10} \end{cases} \tag{4}$$

where σ_{ij} means that the biomass consumed per unit quantity fungi i is $\sigma_i j$ times that of fungi j.So when it comes to other fungi i, the equation is

$$\begin{cases} \frac{dx_i}{dt} = r_{i0}(1 - \frac{x_i}{K_i} - \sum_{j=1,j\neq i}^{n} \sigma_{ij} \frac{x_j}{K_j})x_i = r_{i0}(1 - \sum_{j=1}^{n} \sigma_{ij} \frac{x_j}{K_j})x_i \\ x_i(t_0) = x_{i0} \end{cases} \tag{5}$$

Then we notice that σ_{ij} is a key indicator. If $\sigma_{ij} > 1$, then fungi i consumes more resources than fungi j. On the contrary, if $\sigma_{ij} < 1$, then fungi consumes less resources than fungi j. For a competitive environment with n species of fungi, we can construct a competitive ability matrix as below:

$$\boldsymbol{\sigma} = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \dots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \dots & \sigma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \dots & \sigma_{nn} \end{pmatrix}$$

The matrix $\boldsymbol{\sigma}$ satisfies some properties as below:

1. If $i = j$, then
$$\sigma_{ij} = 1 \tag{6}$$

2.
$$\sigma_{ij} > 0, \sigma_{ij}\sigma_{ji} = 1(i \neq j) \tag{7}$$
Generally speaking, the two fungal populations have the same retarding effect in consuming resources. Specifically, the ratio of the amount of food per unit of fungi i to fungi j is $\sigma_{ij} : 1$, and the ratio of the amount of food per unit of fungi i to fungi j is also $1 : \sigma_{ji}$. Thus, $\sigma_{ij} : 1 = 1 : \sigma_{ji}$, i.e. $\sigma_{ij}\sigma_{ji} = 1$

3.
$$\sigma_{ij} \times \sigma jk = \sigma ik, i, j, k = 1, 2, \dots, n \tag{8}$$
which means that $\boldsymbol{\sigma}$ is a consistent matrix.This indicates that the blocking relationship between fungi of more than three species can be transmitted in equal proportions.

4. According to nature 3, environmental capacity$K_i$the following equation:
$$\frac{K_i}{K_j} = \sigma_{ij} = \frac{1}{\sigma_{ji}} \tag{9}$$

4.3 Data Description

We choose about 10 square meters of land in Liujia Village, Xinliujia Town, Nong'an County, Jilin Province, which is in northeast China. Here is a temperate continental climate, characterized by strong continental nature, short dry and windy spring, warm and rainy summer, cool autumn, cold and long winter. The main herbaceous plants are: bluegrass, wattle, sorrel, plantain, season grass, etc.;woody plants mainly include: cloves and poplars.There is more information in Table 1.[3]

In this area, there are five dominant species of fungi[2] as shown in Table 2.

Table 1: the Basic Information

Altitude	Location	Average Temperature	Annual Precipitation
203m	44.11°N,125.12°E	18°C	500-600mm

Table 2: Dominant Species of Fungi

Name of fungi	Average Number x_i(cfu/g)	r_0
Phoma Putaminum	5.95E+04(x_1)	0.8188016
Green Trichoderma Mould	4.1E+03(x_2)	0.6321236
Penicillium Expansum	1.1E+05(x_3)	0.5792944
Botrytis Cinerea	1.6E+04(x_4)	1.39594
Aspergillus Versicolor	8.2E+03(x_5)	1.013314
total	1.978E+05	-

4.4 Results

Since we have assumed that the given environment is in a steady state, then the number of various fungi is keeping stable, i.e.

$$\frac{dx_i}{dt} r_{i0}(1 - \sum_{j=1}^{n} \sigma_{ij} \frac{x_j}{K_j}) x_i = 0 \tag{10}$$

We use data in Table 2 to solve (6) (7) (8) (9) and (10) to know competitive ability matrix

$$\boldsymbol{\sigma} = \begin{pmatrix} 1 & 5.661969 & 3.363484 & 6.068844 & 4.65789 \\ 0.2145016 & 1 & 0.7214727 & 1.301777 & 1.36278 \\ 0.2973108 & 1.386054 & 1 & 1.804333 & 1.386054 \\ 0.1647760 & 0.7681808 & 0.5542215 & 1 & 0.7681808 \\ 0.2145016 & 0.7338 & 0.7214727 & 1.301777 & 1 \end{pmatrix}$$

and environmental capacity

$$\boldsymbol{K} = \begin{pmatrix} 75033.46 \\ 16094.8 \\ 22308.26 \\ 12363.72 \\ 11815.7 \end{pmatrix}$$

Until now, we can know the number of fungi relationship as below:

$$\begin{cases} \frac{dx_1}{dt} = 0.8188016(1 - \frac{x_1}{75033.46} - 5.661969\frac{x_2}{16094.8} - 3.363484\frac{x_3}{22308.26} - 6.068844\frac{x_4}{12363.72} \\ -4.65789\frac{x_5}{16094.8} \\ \frac{dx_2}{dt} = 0.6321236(1 - 0.2145016\frac{x_1}{75033.46} - \frac{x_2}{16094.8} - 0.7214727\frac{x_3}{22308.26} - 1.301777\frac{x_4}{12363.72} \\ -1.36278\frac{x_5}{16094.8} \\ \frac{dx_3}{dt} = 0.5792944(1 - 0.2973108\frac{x_1}{75033.46} - 1.386054\frac{x_2}{16094.8} - \frac{x_3}{22308.26} - 1.804333\frac{x_4}{12363.72} \\ -1.386054\frac{x_5}{16094.8} \\ \frac{dx_4}{dt} = 1.39594(1 - 0.1647760\frac{x_1}{75033.46} - 0.7681808\frac{x_2}{16094.8} - 0.5542215\frac{x_3}{22308.26} - \frac{x_4}{12363.72} \\ -0.7681808\frac{x_5}{16094.8} \\ \frac{dx_5}{dt} = 1.013314(1 - 0.2145016\frac{x_1}{75033.46} - 0.7338\frac{x_2}{K_2} - 0.7214727\frac{x_3}{22308.26} - 1.301777\frac{x_4}{12363.72} \\ -\frac{x_5}{16094.8} \end{cases} \tag{11}$$

4.5 Conclusions

1. The ratio of fungi consuming resources directly affects their ability to compete in the ecosystem.
2. The less the fungus consumes resources, the faster the fungus grows, and the larger the proportion in the ecosystem, the easier it is to gain a dominant position.
3. The reproduction speed of fungi cannot reach the maximum reproduction speed due to the limitation of natural resources and environmental conditions. In fact, according to (2), at last, the number of fungi has nothing to do with r_0.

4.6 Trend

The equation (11) can exactly explain the short-term trend, so we don't give more details about the short-term trend and will pay more attention on the long-term trend.

Step1: The growth rate of fungi and the rate of population renewal are very fast. Compared with plants and animals, there will be more variation produced by fungi.

Step2: The variation is completely random. In a competitive environment, it may be good for survival, or it may not be good for survival. The former remained and gradually occupied the majority of the population. The latter is naturally eliminated.

Step3: Repeat the above steps, if there is enough variation, then a new species is born.[1] What's more, this model predicts that the new species consumes less resources per unit quantity than the original species.

5 Environmental Changes and Their Impacts

In this section, we first discuss the impact of environmental changes on the decomposition rate of fungi. Then discuss the impact of decomposition rate on competitiveness. Finally, find the change in the number of fungi as shown in Figure 1.

[1]The sign of a new species is reproductive isolation, i.e. the inability to produce fertile offspring.

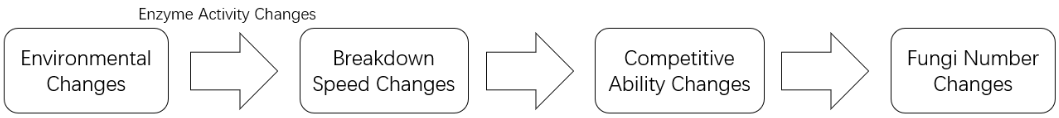


Figure 1: Schematic Diagram of Environmental Change

5.1 Environmental Changes

We choose two necessary elements: temperature and humidity.

5.1.1 Temperature

Enzyme is a very efficient catalyst. The catalysis of enzymes can often reach thousands of times that of inorganic catalysts. Fungi mainly rely on enzymes to break down cellulose and lignin. The enzyme has the strongest enzyme activity and the fastest enzymatic reaction speed within the optimum temperature range. Generally speaking, within a suitable temperature range, for every 10°C increase in temperature, the enzymatic reaction speed can be increased by 1 to 2 times. For most enzymes, when the temperature reaches 60-80°C, most of the enzymes are destroyed and irreversible; when the temperature approaches 100°C, the catalytic effect of the enzyme is completely lost. At low temperatures. The catalytic efficiency also becomes very low.

5.1.2 Humidity

Du Fang et al. found that the correlation coefficient between humidity and the decomposition rate of carbohydrate enzymes is 0.4609, which is significant. When the humidity was changed to be the same as that of the control group, it quickly dropped to close to that of the control group. At the same time, enzymes in different plant materials do not respond to humidity inconsistently, and they work in response to specific cellular environmental conditions.[4]

5.2 BP Neural Network

BP (Back Propagation) neural network is invented by a group of scientists headed by Rumelhart and McCelland in 1986. It is proposed that is a multi-layer feed forward network trained according to the error back propagation algorithm, and is one of the most widely used neural network models.The BP neural network can learn and store a large number of input-output pattern mapping relationships, without the need to disclose and describe this mapping relationship in advance. Its learning rule is to use the steepest descent method to continuously adjust the weight and threshold of the network through back propagation to minimize the sum of squared errors of the network. BP neural network model topology includes input layer, hidden layer and output layer as shown in Figure 2.

We choose five sets of data [4][5][6][7][8][9][10] distributions corresponding to five fungi to build a prediction model. Each set of data has three input parameters: temperature T, humidity H, and the hehyphal extension rate. Since each set of data is the same fungus and has the same moisture tolerance, it is no longer considered.

After consideration, we set up 10 neurons, one-layer hidden layer, and the activation function, which ReLU(Rectified Linear Unit,$f(x) = max[0, x]$) as shown in Figure 3. We also set 70% of the samples as the training set, 15% as the test set and 15% as the validation set.

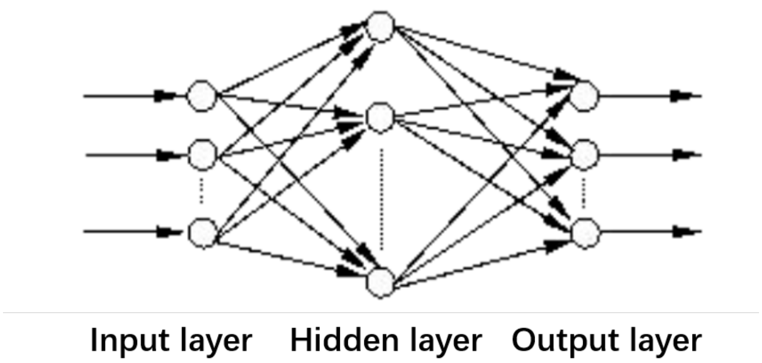


Figure 2: BP Neural Network

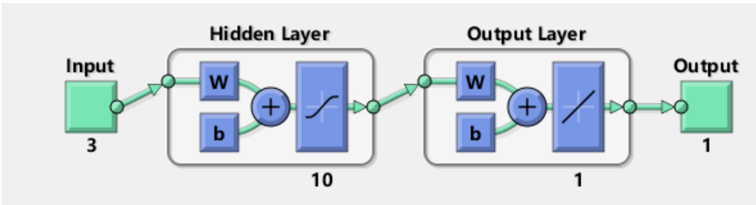


Figure 3: BP Neural Network

The results of BP neural network are as shown in Figure 4.

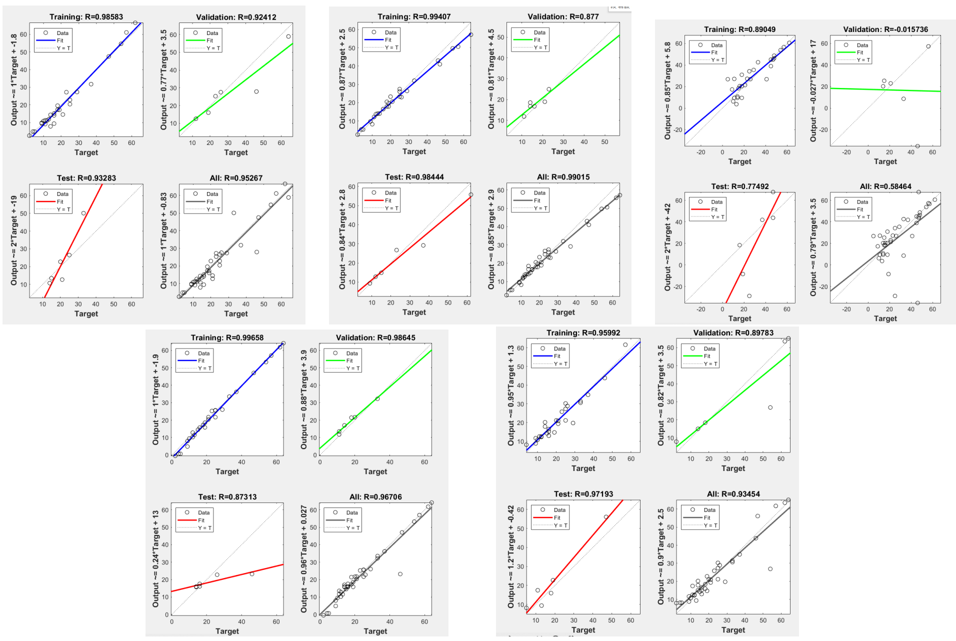


Figure 4: BP Neural Network Fitting Results

5.3 Impacts

Based on the definition of σ_{ij}, we know that

$$\sigma_{ij} = \frac{v_j dt}{v_i dt} = \frac{v_i}{v_j} \tag{12}$$

We use the Equation (12). BP Neural Network and Multi-Fungi Competitive Model to predict v under different temperature and humidity the number of fungi under different temperature as shown in Figure 5, Figure 6 and section 8.

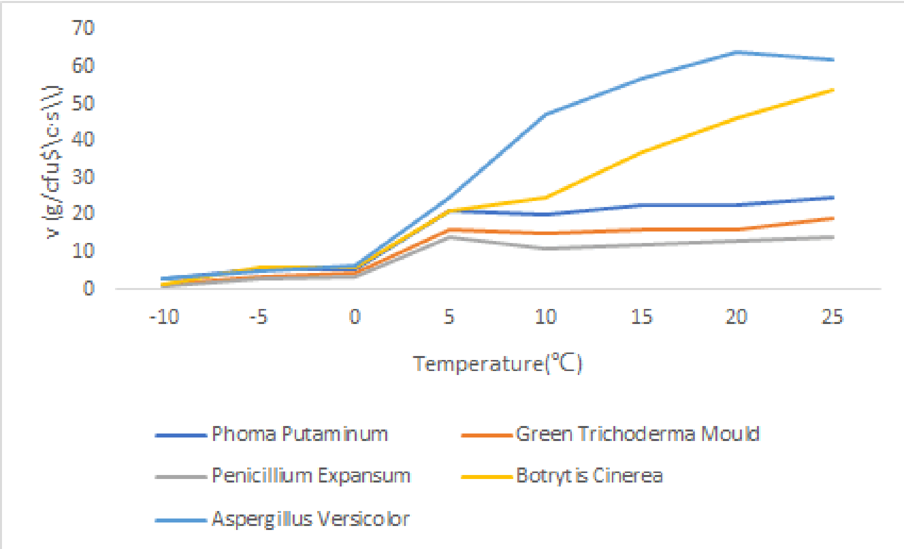


Figure 5: The Relationship between v and T at H 50%

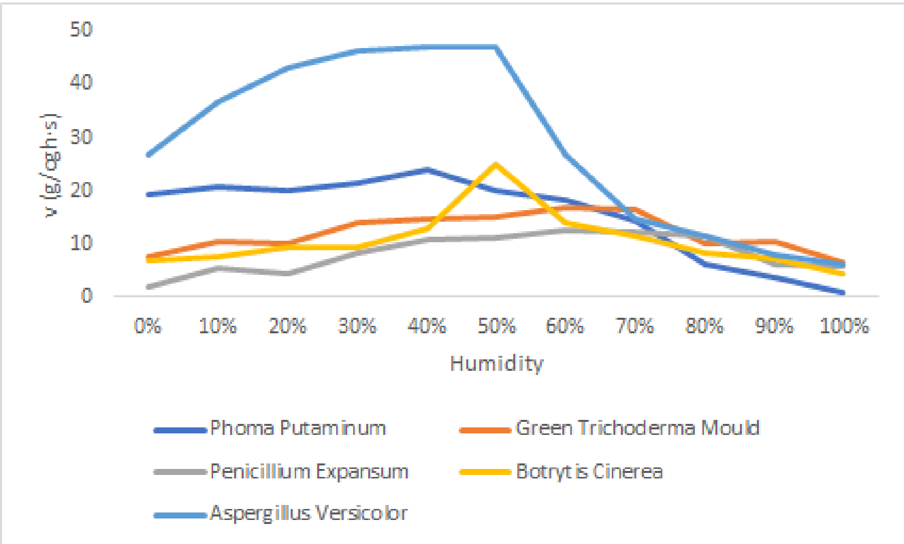


Figure 6: The Relationship between v and H at 15 °C

We noticed that the changing trend of v for various fungi is roughly the same. This may be because the enzymes they use are similar in structure and therefore similar in properties.

6 Forecast in Different Environments

We set the following parameters[2]:

	arid	semiarid	temperate	arboreal	tropical rain forests
Temperature($^{\circ}C$)	20	20	18	22	25
Humidity(%)	0	15	30	40	50

The results are in Table 3.

Number of Fungi	arid	semiarid	temperate	arboreal	tropical rain forests
Phoma Putaminum	4.5E+04	5.85E+04	5.95E+04	7.9E+04	5.95E+04
Green Trichoderma Mould	3.6E+03	3.8E+03	4.1E+03	4.6E+03	4.3E+03
Penicillium Expansum	1.6E+05	8.8E+04	9.3E+04	1.2E+05	2.2E+05
Botrytis Cinerea	9.5E+03	1.1E+04	1.6E+04	1.7E+04	1.9E+04
Aspergillus Versicolor	7.4E+03	8.9E+03	8.2E+03	8.2E+03	9.9E+03

Table 3: Forecast in Different Environments

In arid environments, Penicillium Expansum is a relatively dominant species. In humid environments, the others are relatively dominant species. However, the proportion of each species has not changed significantly.

7 Species diversity

We tested the time for the existence of different types of fungi, removing all fungi with the same K value in equal proportions, and the average time for their biomass to return to K as shoen in Table 4.

ave time(h)	10% of K	20% of K	30% of K	40% of K	50% of K
5-fungi system	6	20	37	44	56
4-fungi system	7	26	39	48	64
3-fungi system	7	28	42	62	65
2-fungi system	16	29	44	79	85
1-fungi system	29	29	45	104	117

Table 4: Average Recovery Time

This indicates that fungal systems with richer biodiversity have stronger resilience. When the ecosystem faces severe impacts, systems with more biodiversity can recover faster and decompose ground litter faster.

8 Sensitivity Analysis

This paper simulates the effect of temperature and humidity changes on the rate of fungi decomposing ground litter, which in turn affects the proportion of various fungi populations. We set different humidity and temperature to test the sensitivity of the model in Table 5 and Table 6.

Through the above table, the number of fungi has not changed much, and it can be intuitively found that the model is realatively stable.

9 Strengths and Weaknesses

9.1 Strengths

For a fungus, we use a single linear function to express the relationship between the number of fungi and the inherent growth rate r, and use the traditional Logistic model to construct the relationship function between the number of fungi and time. For the decomposition of fungi, we

Number of fungi	10%	20%	30%	40%	50%	60%
Phoma Putaminum	5.10E+04	5.40E+04	5.65E+04	5.75E+04	5.85E+04	5.85E+04
Green Trichoderma Mould	4.05E+04	4.10E+04	4.15E+04	4.25E+04	4.25E+04	4.20E+04
Penicillium Expansum	8.85E+04	9.15E+04	9.05E+04	9.25E+04	1.05E+05	1.10E+05
Botrytis Cinerea	1.50E+04	1.55E+04	1.55E+04	1.65E+04	1.75E+04	1.70E+04
Aspergillus Versicolor	8.15E+04	8.15E+04	8.20E+04	8.30E+04	8.25E+04	8.20E+04

Table 5: Relationship between x and H at 15°C

Number of fungi	0°C	5°C	10°C	15°C	20°C	25°C
Phoma Putaminum	5.15E+04	5.35E+04	4.55E+04	4.95E+04	5.95E+04	5.95E+04
Green Trichoderma Mould	4.50E+03	4.20E+03	4.20E+03	4.32E+03	4.20E+03	4.30E+03
Penicillium Expansum	9.60E+04	8.70E+04	9.30E+04	1.30E+05	8.20E+04	9.30E+04
Botrytis Cinerea	1.64E+04	1.66E+04	1.69E+04	1.67E+04	1.65E+04	1.61E+04
Aspergillus Versicolor	8.00E+03	7.80E+03	7.80E+03	7.90E+03	8.20E+03	8.10E+03

Table 6: Relationship between x and T at H 50%

extended the Logistic model to the competition model, adding the effects of natural resources and environmental resources. For these two models, they are widely used and flexible to use. They can change the model and function at any time by changing the environmental variables, and have a good fitting effect with the experimental data, so they are easier to use and explain.

For the prediction of species combination trend in different environments, we use the Rectified linear unit model in neural network. Compared with other neural network functions, this model has a faster convergence speed, and its derivative is more easily obtained. In the region of x > 0, it prevents the gradient from disappearing and makes the mesh sparse.

9.2 Weaknesses

Logistic model fitting function is "s" type, the process of transformation to probability is nonlinear, the change of intermediate probability is very large and sensitive. And Logistic model does not take into account the impact of sudden and drastic changes in the environment, and the genetic, variation and selection of species are not taken into account, so it is an ideal laboratory model. For Rectified linear cell model, the output is not zero mean, and the Dead ReLU Problem may appear.

10 Practical Application

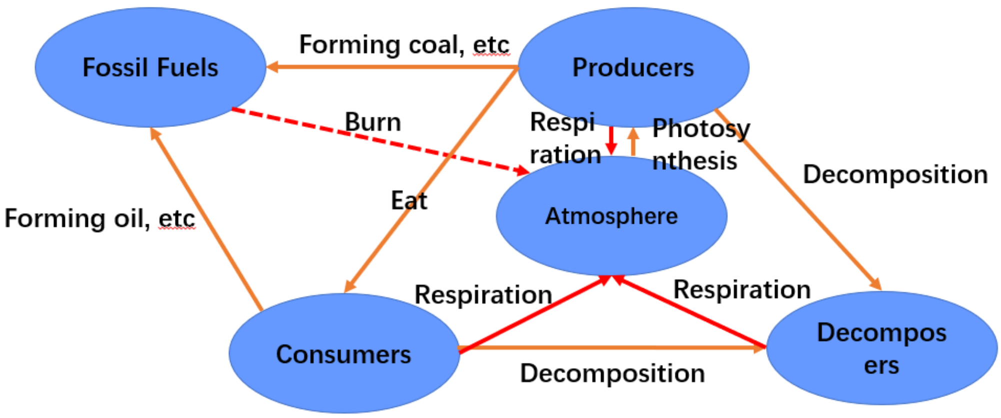
Through the establishment of mathematical model, fitting function and data analysis, we discussed the two key characteristics of fungi: growth rate and water tolerance, and the effect of the interaction between different fungi on the decomposition rate of fungi. Then through the analysis of neural network, we can analyze the colony environment under different high diversity environment, and predict that the decomposition ability of fungi is related to the surrounding natural environment (including temperature humidity and so on), its two important characters, and the interaction between different fungi.

We hope that through the analysis of mathematical modeling, we can provide a reasonable solution for the global problem of fungal decomposition of tree residues and wood fibers. For the future research and improvement direction, we need more data for more accurate prediction and analysis, at the same time to adapt to different environment and climate analysis and problem-solving ability. It should also include different fungi in each stage of the decomposition process, further clarify the relationship between the characteristics of fungi and the decomposition rate over time, and finally provide some support and ideas for the research on the decomposition of compounds in the earth's carbon cycle.

Appendices

Appendix A Article of Results

Carbon cycle is a phenomenon of carbon exchange and circulation in the earth's biosphere, atmosphere, lithosphere and hydrosphere. The carbon cycle in the biosphere is mainly driven by photosynthesis of green plants and respiration of organisms. Among them, the decomposition of various organisms, mainly by respiration, enables the separation of carbon from organic compounds, allowing carbon to enter the cycle and be reused in other forms. However, some of the organic compounds are difficult to be decomposed by plants, such as wood fiber in humus. Fungi play an important role in the decomposition of wood fibers.



Carbon cycles Diagram

Fungi are decomposers. The unique decomposing ability of some fungi plays an important role in decomposing wood fiber and promoting carbon cycle. In the real environment, it is often a community composed of a variety of different fungi, which decompose wood fiber together under the interaction of various fungi. At the same time, different kinds of fungi have different ability to decompose wood fibers and have different effects on other kinds of fungi. In different environments, fungi play different roles in decomposition. After some experimental data analysis, as well as the simulation of population competition model and neural network model, we get some conclusions and applications about the process of fungi decomposing wood fiber.

For single species of fungi, the growth of fungi is not limited under ideal conditions, and conforms to Malthus model and increases exponentially. However, in the natural environment, the growth of fungi population conforms to the Logistic model, and its growth is restricted by its own number to a certain extent, and the higher the density of fungi, the more obvious its inhibition effect on itself. The growth rate of fungi not only depends on their own characteristics, but also is affected by environmental factors. The temperature and humidity are the two most important factors. Under the suitable humidity conditions, when the temperature reached the optimum temperature, the growth rate of fungi was the fastest, and the decomposition of wood fiber was also the fastest. Relative to the optimum temperature, the optimum humidity for fungus growth is not obvious. When the humidity is very low, most of the fungi will go into dormancy. But in the range of water niche breadth width, increasing humidity can improve the growth rate and decomposition efficiency of the fungus. The experimental data show that, generally speaking, fungi with wider water niche width (i.e. stronger humidity tolerance) are more likely to adapt to complex environment, but at the same time, their growth rate is often slow.

In the real environment, a variety of different fungi coexist, and their interaction is also an important factor affecting the growth rate and decomposition rate. Adding the influence of environmental factors, we can get the following influence chain: environmental factors affect the growth rate of fungi, the growth rate of fungi affects the decomposition rate of wood fiber, and the decomposition rate affects the effect of fungal interaction. According to the data, most of the relationships among the fungi that decompose wood fibers are competition, and they inhibit each other. In other words, under the same suitable environmental conditions, fungi with faster growth rate can often be dominant. Without considering the influence of temperature, if the humidity condition is bad (such as high humidity environment), the fungi with narrow water niche width will be greatly inhibited, and the fungi with wide water niche width will be dominant. Through this phenomenon of population competition, we can roughly infer the change trend of local climate by investigating the species and dominance degree of dominant fungi.

Compared with a single fungus, the decomposition efficiency of a variety of fungi in different environmental conditions can always be maintained at a high level. Through the model prediction, we can also get: when the environmental conditions change violently or repeatedly, a variety of fungi can not only ensure the decomposition rate, but also ensure the safety of each strain to the greatest extent, so that it will not be extinct. In contrast, the ability of a single fungus to resist this change is very weak, even facing the risk of extinction. Through such a prediction analysis, we can verify from the perspective of fungi that biodiversity plays an important role in the stability of the ecological environment.

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