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T1 ________________	**2107451**	F1 ________________
T2 ________________	Problem Chosen	F2 ________________
T3 ________________	**A**	F3 ________________
T4 ________________		F4 ________________

2021
MCM/ICM
Summary Sheet

Let's decompose,fungi!

In the carbon cycle process, the decomposition of organic matter, especially the degradation of plant material and woody fibers involving fungi, is an essential link. We explore the relationship between fungal properties (growth rate and moisture resistance) and the decomposition rate of wood fibers to better understand the relationship and mechanism between the degradation of plant material and woody fibers and fungi.

Firstly, considering multiple factors, through data-based regression analysis, we initially establish a multiple linear regression model of the decomposition rate of wood fiber, and explain the rationality of the model from the perspective of biology and ecology. At the same time, from a mathematical point of view, we established a mathematical model containing an exponential relationship between fungal growth rate and fungal moisture resistance-the fungal growth rate model, which correlates these two biological characteristics of fungi. And the actual data verifies the rationality of this model.

Secondly, the decomposition of wood fibers by fungi in nature is often the result of the joint action of different populations and there are also interactions between fungal populations, Therefore, we use the growth rate and moisture resistance of fungi as the standard according to the K-Means clustering algorithm and the elbow rule to cluster fungi. In order to analyze the interactions within and between the fungal categories. Then, we optimized and improved the previously established fungal growth rate model based on the Monod equation in microbial dynamics and the theory of interaction between populations, and obtained a fungal growth rate model combined with interaction. We verify the rationality of the model by listing examples of interacting fungal populations under ideal conditions. The final result achieves the unity of theory and practice.

Thirdly, according to the optimized fungal growth model. We discuss and analyze the dynamics of the interactions in terms of long-term and short-term action time, revealing the principles of these two phenomena in nature. In addition, we analyzed the sensitivity of the model to rapidly changing natural conditions and tried to explain it from a biological perspective.

Then,in predicting the strengths and weaknesses of each fungal group and the likely combinations of fungi to survive, we considered the possible conditions in different climatic environment,including arid, semiarid, temperate, arboreal, and tropical rain forests.Combined with the analysis and experimental data of previous papers, we concluded that fungi with a high growth rate and moisture tolerance are more likely to survive when the environment is relatively stable.While when the weather is changeable,fungi with a large water niche width are more competent.We also further discussed the dependence between fungi and the environment and found out the possible seasonal changes of fungi in different areas.

Finally,our model successfully shows the relationship between fungal species diversity and decomposition rate. When the fungal species diversity is higher, the decomposition rate will also decrease. Because decomposition will emit carbon dioxide, it also indirectly implies the relationship between species diversity and carbon dioxide. It has positive significance for environmental issues related to greenhouse gas emission reduction, and is helpful to optimize the global carbon cycle and co-build a beautiful earth.

Contents

1 Introduction

Carbon cycle describes the continuous exchange and movement of carbon on the earth.And in the carbon cycle process, the decomposition of organic material plays important role,which updates and changes the existing form of carbon.In this process ,especially the degradation of plant material and woody fibers involving fungi, is an essential link.

The author of a recent paper which researches on the decomposition wood by fungi has pointed out the fungal characters that determine the decomposition rate, and figured out the relationships between some characters. Particularly, slow growing fungal strains can survive and grow better in the presence of environmental changes.

In this problem,we are asked only to consider two traits of fungi——growth rate and moisture resistance.Our main goal is to model the decomposition of wood fibers on a given land and in the presence of multiple types of fungi that decompose wood fibers in the fixed area.

According to the requirements of the competition,our work can be briefly generalized into five parts.

1. We initially use regression analysis to establish a multiple linear regression model of the decomposition rate of wood fiber .And established a mathematical model of the growth rate.
2. Use K-Means algorithm to incorporate the interactions between different species of fungi which has different traits.Analyse the interactions between different types. Optimize and verify the growth rate model.
3. Analyse the dynamics of the interactions and examine the sensitivity to rapid fluctuations.
4. Predict the relative strengths and weaknesses of each species and its possible persistent species combination and apply to five different environments.
5. Describe how the diversity of fungal communities of a system impacts the overall efficiency of a system with respect to the decomposition of the ground litter.Predict the importance and role of biodiversity in the varying degrees of variability in the local environment

2 Preparation of The Models

2.1 Assumptions

1. The process of decomposition happens on a given land.
2. The species of vegetation in a given area do not change.

3. Decomposition is carried out in a limited space,which means there exists a closed space that can contain decomposition system.
4. Ignore the destructive damage to the decomposition system caused by unexpected events, such as man-made damage, volcanic eruption...
5. Based on the above four hypotheses, it can be considered that the biomass concentration and biomass of fungi and woody fibers are equivalent in an unit space.

2.2 Notations

The primary notations used in this paper are listed in **Table 2**.

Table 1: Notations

Definition	Symbol
Decomposition rate	D
The decomposition donated by the *i* th specices of fungi	D_i
Regression coefficient	α_{ij}
The growth rate of the *i* th specices of fungi	E_i
Moisture tolerance	M
Moisture tolerance of the *i* th specices of fungi	M_i
Temperature seasonality	T_s
Temperature annual range	T_R
Percipitation of westtest quarter	P_w
Biomass	C_{xi}
Residual amount of wood fiber	R

3 The Preliminary Model

3.1 Carbon Cycle and Fungi

The carbon cycle describes the cycle of exchange of carbon in the biosphere, lithosphere, hydrosphere, and atmosphere.

As one of the most important cycles on Earth, the process of the carbon cycle can be described as the absorption of carbon dioxide from the atmosphere by plants on land and in the sea, through biological or geological processes and human activities, and then returned to the atmosphere as carbon dioxide.(See Figure 1 for details.)

In the process of biological participation in the carbon cycle, one of the main activities is microbial participation in the decomposition of compounds, which changes the form of carbon element to participate in the carbon cycle.

A key component in this process is the decomposition of plant material and wood fibers[11], with fungi being the main factor in the decomposition of wood fibers.

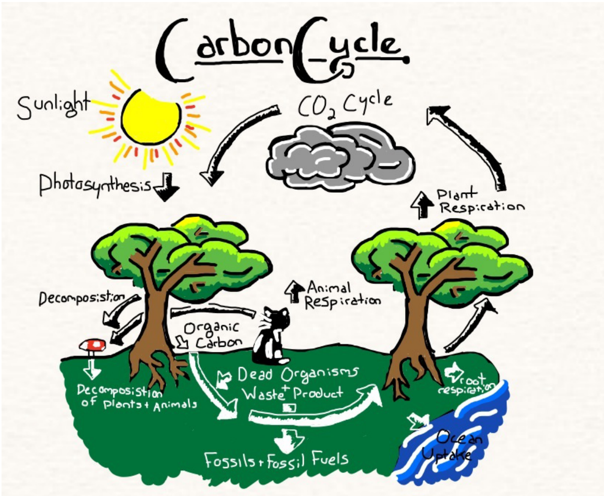

Figure 1: carbon cycle [1]

3.2 Construction of Fungal Growth Rate Model

3.2.1 Brief Introduction of Modeling Process

To explore how fungi are involved in the decomposition of plant material and wood fibers.It is necessary to know more about the biological characteristics of the fungi involved in decomposition——the growth rate of the fungi.

At this point, we should model the growth rate of the fungus first.This step is not unnecessary and will be crucial to our understanding and subsequent modeling.

We took the several steps to model the growth rate of the fungus.

Initially, we wanted to construct a linear model to describe the rate of fungal growth. However, in repeated experiments and comparisons, we found that the traditional linear model was not a good indicator of the growth rate of fungi from a statistical point of view.

However, from the two pictures provided in the question, it can be concluded that there is an exponential relationship between the growth rate of fungus and its moisture tolerance.

When the exponential model is used to describe the relationship between the two, we find that the fitting effect is quite satisfactory.

[1]https://www.lingholic.com/wp-content/uploads/2014/06/Carbon-cycle.jpg

3.2.2 Verify and Interpret Mechanism

We carefully analyzed the data of the relationship between moisture tolerance and decomposition rate given in the question, and found that moisture tolerance had a significant impact on decomposition rate.

In order to prove our point of view, we draw the **figure 2** of moisture tolerance and growth rate, because growth rate will affect decomposition rate.

If we find a significant relationship between moisture tolerance and growth rate, we can infer that there is a relationship between moisture tolerance and decomposition rate.

This hypothesis is also consistent with the findings of Daniel S. Maynard et al.[3], whose analysis revealed a fundamental balance between moisture tolerance and competitiveness, i.e., fungi with broad thermal and water niches exhibit low displacement capacity.

The magnitude of this tolerance tradeoff is partly related to the environmental conditions in which the fungi are located, in which the thermal niche traits show the strongest climatic relationship.

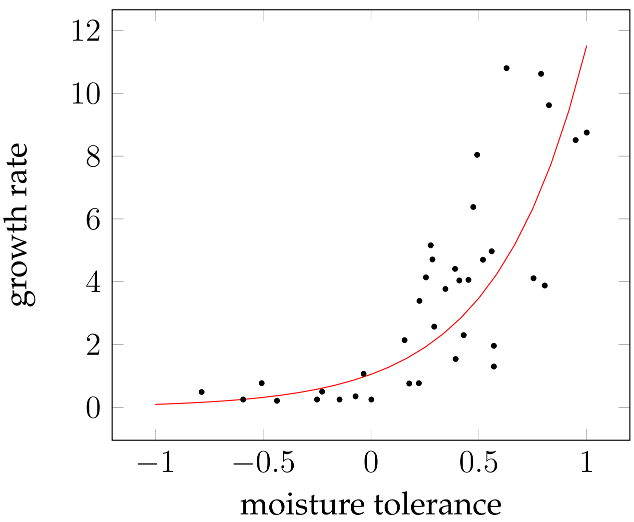

Figure 2: growth rate curve of moisture tolerance

3.2.3 Simplified to Mathematical Model

Set E as the growth rate, a, b, c as constants, and m as moisture tolerance.

$$E = ae^{bM} + C \tag{1}$$

3.3 Construction of Decomposition Rate Model

3.3.1 Brief Introduction of Modeling Process

In nature, the decomposition process of lignin fiber [] is usually the result of many factors. Therefore, in order to establish the decomposition rate model of wood fiber, we will explore from the perspectives of biological factors and natural environment factors, extract the main influencing factors, and finally get the decomposition model of wood fiber.

In the preliminary decomposition rate model of lignin fiber, we adopted the most widely applicable multiple linear regression model.The specific implementation process is as follows:

1. According to the data provided by the data set, multiple linear regression analysis was conducted between the decomposition rate of lignin fiber and the factors that might be related to it.

   Primary screening was conducted according to the significance level of each independent variable to obtain the major variables with statistical significance.

2. Select the main variables selected in Step 1.According to relevant literature, it is verified and explained in terms of biology and environment.

   For the main variables that lack rationality in practical sense, the deletion operation is carried out.The multiple linear regression model of lignin fiber was established preliminarily.

3.3.2 Verify and Interpret Mechanism

Having established and completed the mathematical model of the growth rate, we then proceeded to establish the mathematical model of the decomposition rate.

Four variables——growth rate, temperature seasonality, annual temperature range, and rainfall in the wettest months, were found to have significant effects on fungal decomposition rate, i.e., 122 day residual mass, by multiple regression analysis of significance.We have tried to analyze from a theoretical point of view why these four variables have a significant effect on the decomposition rate.

1.Growth rate——Fungi need to absorb nutrients from substrates for growth, and the speed of growth reflects the speed of absorption of nutrients by fungi. McGuire and Kristal pointed out in their paper that in classical competition theory[4], when organisms have similar ecological characteristics, competition for a resource either maintains diversity through niche differentiation or leads to the loss of diversity through the extinction of inferior competitors. Exploitation competition, in which one microbe takes up a resource faster than another, allows a fungus to absorb nutrients more quickly as its growth rate increases.The growth rate was a significant factor in the decomposition rate.

2.Temperature seasonality——The seasonality of temperature reflects the temperature difference throughout the year, but if the temperature difference is too large, the growth rate of fungi will be affected. Through the linear model, we can preliminarily understand that when the temperature difference is too large throughout the year, the growth rate will decrease, and we can also conclude that when the growth rate of fungi slows down, the decomposition rate of fungi will be significantly reduced.So temperature seasonality will also be a significant factor in our model.

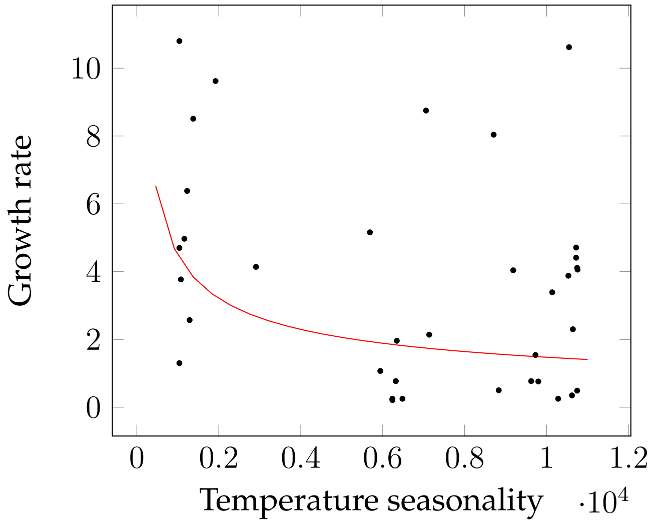

Figure 3: growth rate curve of Temperature seasonality

3.Annual temperature range——The annual temperature range, which reflects the extent of annual temperature change, is an important local measure of climate change.The larger the annual temperature range, the greater the likelihood that the temperature will not be within the range of enzyme activity, which will have a significant impact on the final decomposition rate.If the temperature difference is large, it means that in winter, the enzyme will not be able to maintain a high activity, thus affecting the rate of absorption of nutrients by the fungus,reduce growth rate in the **figure 4**,and ultimately affecting the size of the decomposition rate.

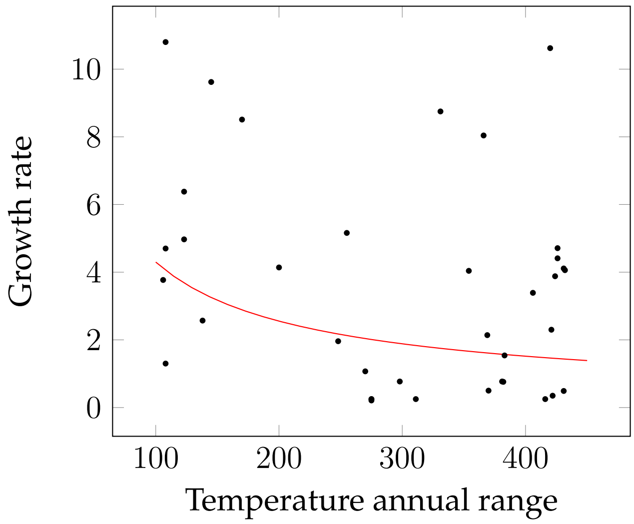

Figure 4: growth rate curve of Temperature annual range

4.Precipitation of wettest month——The amount of precipitation is an indirect indicator of how wet the air is, and the wettest months tend to represent how much rain falls throughout the year.The figure below reflects the relationship between precipitation and growth rate in the wettest months through linear fitting in the **figure 12**.The higher the precipitation, the higher the fungal growth rate, so we can infer the relationship between the precipitation in the wettest months and the decomposition rate.

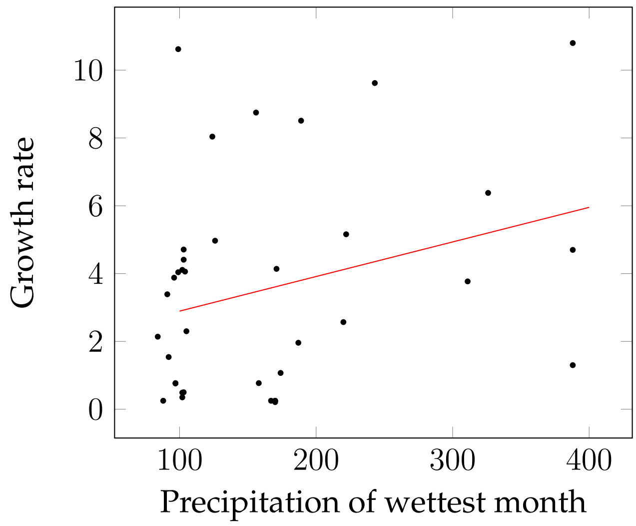

Figure 5: growth rate curve of precipitation of wettest month

3.3.3 Simplified to Mathematical Model

$$\begin{cases} D = \sum_{i=1}^{n} D_i \\ D_i = \alpha_{i1} E_i + \alpha_{i2} T_s + \alpha_{i3} T_R + \alpha_{i4} P_w \end{cases} \tag{2}$$

4 The Interactions Between Different Species of Fungi

4.1 Fungi Classification

In order to further understand the interaction between fungal populations, K-means clustering, systematic clustering algorithm and elbow rule were adopted to conduct cluster analysis according to the characteristics of fungi themselves.

The detailed flow chart is as follows (**figure 6**).

4.1.1 Assumptions Based on the Above Clustering Results

The pedigree diagram obtained by the system clustering algorithm(**figure 7**).

In order to obtain the optimal number of clustering K,we compared the aggregation coefficients of different cluster numbers, and obtained the final optimal number of clusters by elbow rule is 4 (K=4).The classification of these four types of fungi. Based on the above clustering results, we can make the following assumptions:

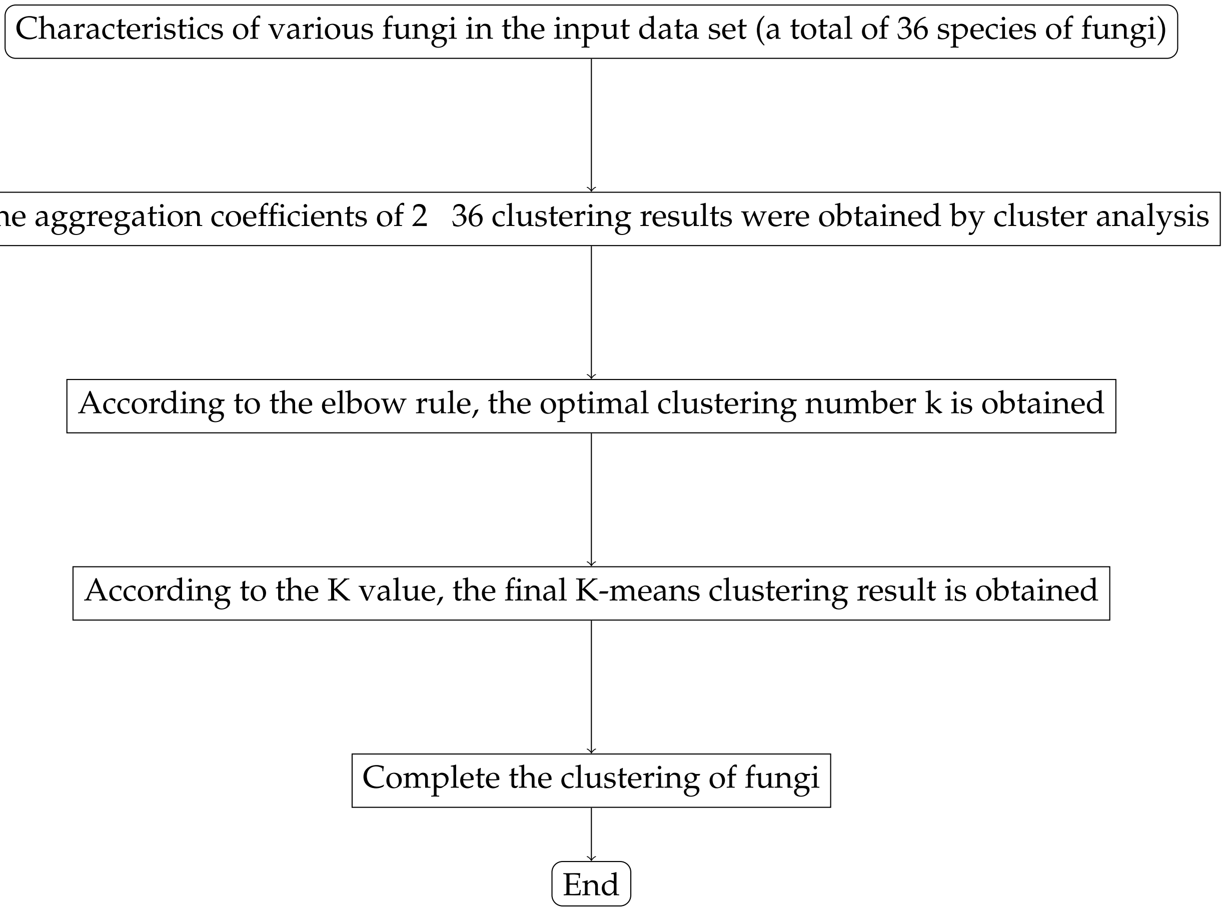

Figure 6: Flow chart of clustering

1. Fungi belonging to the same category, which have highly similar biological traits, play similar roles in the decomposition process of wood fibers.
2. Different types of fungi, including those with relatively low similar biological traits, play different roles in the decomposition of wood fibers.

4.1.2 Analysis of Clustering Results

Through K-means clustering, we finally divided 37 species of fungi given in the data set into three types(**figure 8**).

The following is an explanation of the clustering results.

The first type (a total of 12 species) tended to have the lowest moisture tolerance and the lowest growth rate of the three types.In addition, the low competitive ability means that this species is at a disadvantage in competing for natural resources, but this type has the widest water niche widths of the three types of fungi.These fungi's ability to better adapt to environmental changes makes up for their lack of competitive species.

The second type of fungi (19 species in total) has moderate moisture tolerance and growth rate, and their water niche widths and inter-population competitiveness are also between the first and second type of fungi.

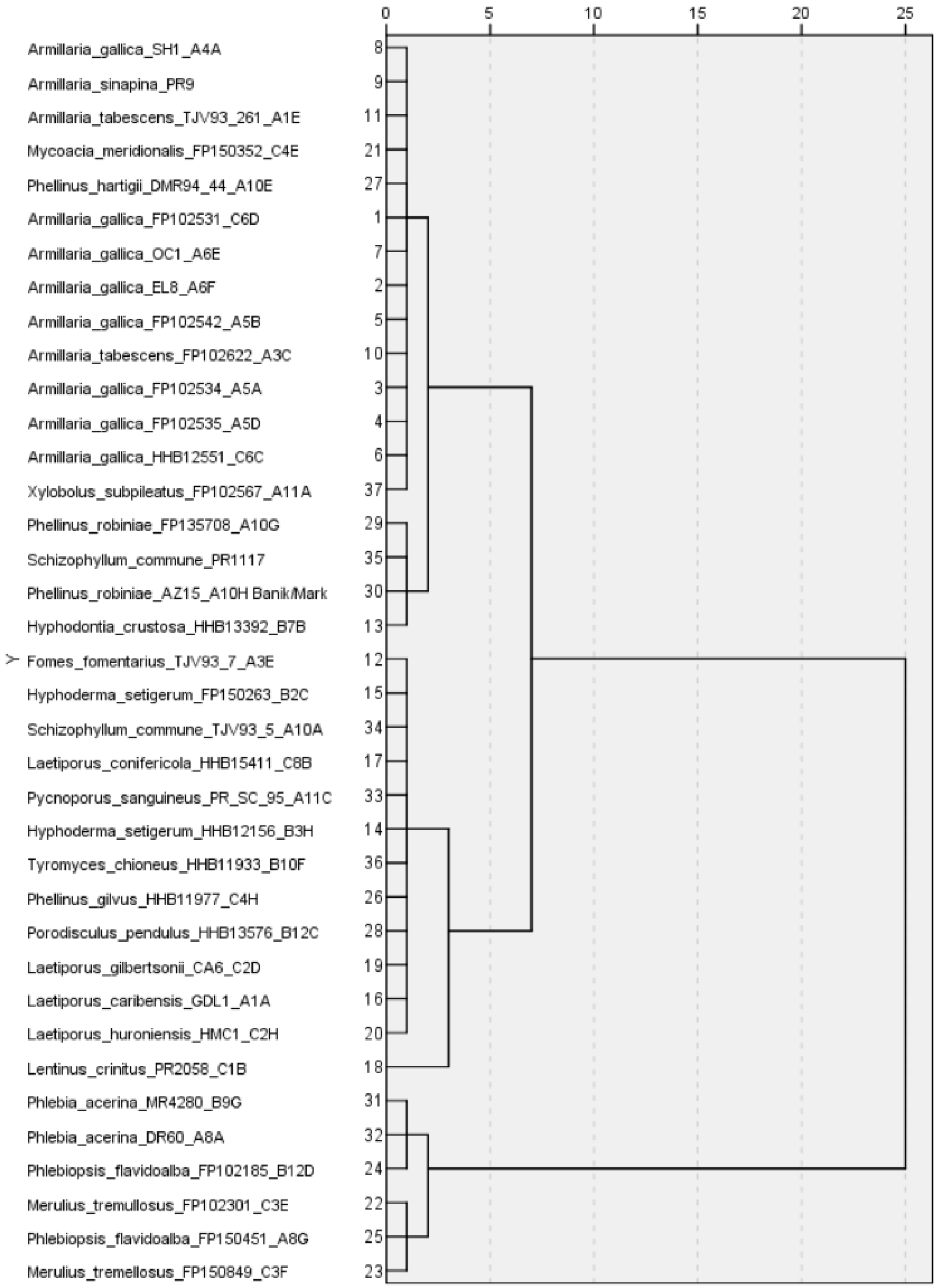

Figure 7: Pedigree diagram

The third type (a total of six species) has the strongest moisture tolerance and fastest growth rate, because the first two types compete for natural resources.But that doesn't mean it's any better adapted to its environment.It has the smallest number of species.The narrowest water niche widths mean that these funji are also poor at adapting to environmental changes.

In fact, the above conclusions are consistent with the opinion of Daniel S. Maynard et al. in the paper[3].

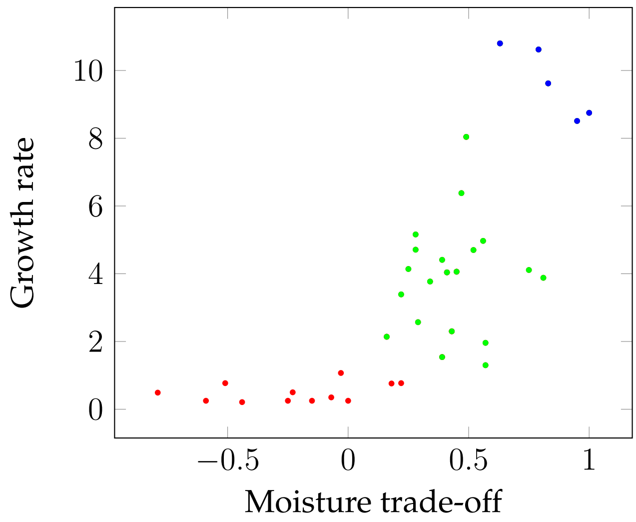

Figure 8: K-means clustering results

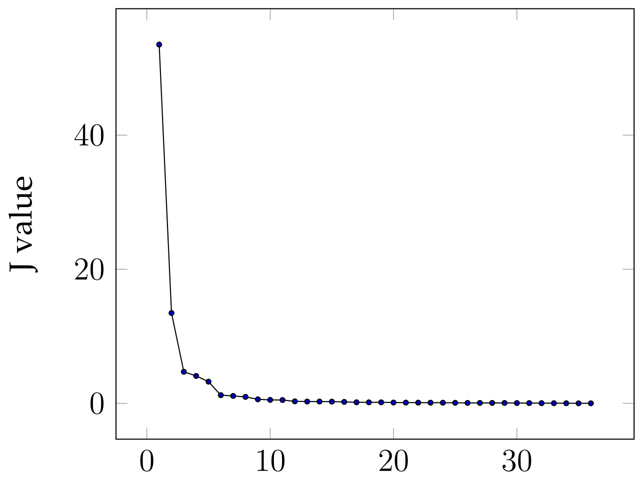

Figure 9: J curve

4.2 The Merging of Fungal Interactions

In the previous part, we gave a specific classification of fungi... Now let's look at the interaction between fungi in two ways. For fungi of the same class, due to the high similarity of biological characters, the same class also showed similar relationship in the decomposition process of wood fiber. Therefore, in order to simplify the model and further analysis, we adopted the following operation: the fungi closest to the cluster center in each category were selected as the representative of this category.Since the influence of similarity plays a major role, the differences within categories can be ignored.

For fungi between different classes Fungi of different categories have low similarity in their biological traits. On the one hand, they undertake different tasks in the decomposition process of wood fibers; on the other hand, they compete for resources, which is directly reflected in the influence of their respective growth rates. In fact, based on the data set provided[3], we can modify the mycelium density term in the fungal growth rate model and take into account the evolution of the population.

4.3 The Optimization of The Preliminary Model

In the previous chapter, we have obtained the models of fungal growth rate and lignofiber decomposition rate. Obviously, this model does not take into account the interaction between fungi, which is still discrepant from the real model. In this chapter, we carry out specific analysis, take into account the interaction within and between populations, and extend the preliminarily established multiple linear regression model to the generalized multiple linear regression model.

4.3.1 Simplified to Mathematical Model

We need to revise the model in the previous chapter because different types of fungi all need to absorb certain organic matter in the wood fiber to maintain their growth, so there is a competitive relationship between them. For simplicity of form, we introduce biomass C_{xi} as one of the variables. Based on the Monod equation in microbial dynamics and the traditional inter-population competition model, the following model is constructed[14]:

$$\begin{cases} E_i = \frac{\mu_i R}{k_i + R} \cdot C_{xi} \\ R = 1 - D \\ \frac{\partial C_{xi}}{\partial t} = E_i - \frac{\partial D}{\partial t} \cdot C_{xi} \end{cases} \tag{3}$$

For better illustration, we enumerate only two types of fungi competing, and assume that the natural environment remains unchanged, and consider C_{xi} as a function of time t.

The above system of equations is an ordinary differential system. If $\mu_1 > \mu_2$, in the steady-state solution $\bar{C_{x_2}} = 0$. In fact, μ_1 and μ_2 is actually related to the maximum growth rate E_{imax} in the microbial dynamics, which indicates that the species with the highest growth rate will become the dominant species, and the species with the lowest growth rate will face elimination, which also reflects the natural law of survival of the fittest.

4.4 The Interactions Between the Different Types of Fungi

In order to analyze the dynamics of the interactions which include both short- and long-term trends, let us might as well start with decomposition rate models contributed by each type of fungi. Because the effect of fungi on the decomposition rate is a direct reflection of the interactions between fungi.

Some parameters related to weather or climate can be regarded as constant values over a short period of time, so the degree of decomposition of lignin fibers in which fungi are involved is linearly related to this period of time.In addition, after determining the species of fungus, its moisture tolerance is fixed, so we can obtain:

$$D_i \propto E_i$$

This suggests that the rate of decomposition during this time period depends on the dynamics of the interactions between the fungi.At this time, the dominant factor of interaction among different species of fungi is the competition for resources and space among fungal populations.

At this point, the dynamics of the interactions between fungi can be determined by the equations in the previous chapter.

Therefore, the decomposition rate contributed by various fungi can be understood as the cumulative effect of fungi and natural factors over time.

At the same time, as the content of wood fiber changes, the dynamics of the interactions between fungi will be affected.

Specific relationships can be analyzed through the equations, but it is important to note that natural environmental factors have also played a role.

4.5 Examine the Sensitivity Rapid Fluctuations in the Environment

In the linear model of decomposition rate, growth rate has maximum weight among the variables. When the natural environmental conditions fluctuate rapidly, only when the fluctuation range is severe enough, the influence of natural environmental factors could be further expanded.

According to the equations 3, when the natural environmental conditions fluctuate rapidly, the derivative value of environmental variables with respect to time changes rapidly, which will also lead to the rapid change of partial derivative value of wood fiber decomposition rate and fungus growth rate with respect to time.

Considering the survival mechanism of fungal population, the fungi with faster growth rate have a narrow niche width, which means that they are less adaptable to the rapid fluctuations in the environment . However, fungi with low growth rate and humidity tolerance can adapt to the changes of natural environment. Therefore, the rapid fluctuation of natural environmental conditions is often accompanied by population succession.

5 Predictions About The Relative Advantages And Disadvantages

5.1 Predictions About The Relative Advantages And Disadvantages For Each Species And Combinations of Species

In the previous section, we have divided the 37 fungal species given in the data set into three broad categories.

The first type of fungi (18 species in total) has low moisture tolerance, low growth rate and high water niche widths.

The second type of fungi (13 species in total) has moderate moisture tolerance and growth rate, and their water niche widths are between the first and second type of fungi.

The third group (a total of six species) has the highest moisture tolerance and fastest growth rate, but the narrowest water niche widths.

To a large extent, growth rate reflects the ability of fungi to compete for natural resources. We made a regression analysis of growth rate and competitiveness ranking, and found that there was a positive correlation between the two.

In the case that the environmental humidity does not exceed the tolerance range of fungi, those with a fast growth rate will undoubtedly occupy more resources, thus establishing advantages, rapid growth and reproduction, while those with a slow growth rate will be in a disadvantaged position.

The moisture tolerance is a combination of many factors, which to some extent reflects the survival ability of fungi, and also reflects the maximum tolerance of fungi to environmental humidity.The more moisture tolerant the fungus is, the more humidity it can live in.When the ambient humidity exceeds the moisture tolerance range, the fungus will die.

The water niche width reflects the ability of fungi to adapt to environmental changes.The higher the width of the water niche is, the less it is affected by the same environmental change, that is, the stronger the resistance is. Fungi with smaller niche widths are more likely to die in the face of short, rapid changes in weather.

Therefore, for the strains with low growth rate and low moisture tolerance, the wider water ecological width makes up for their lack of competitiveness to some extent.

Based on the model established by the second question, we conclude that the presence of one fungus can inhibit the number of other fungi.On the other hand, there is interdependence and cooperation between different strains to complete the decomposition[13].In the long run, under a relatively constant external environment, through analysis, we can find that the strains with fast growth rate and slow growth rate can often coexist for a long time, because the strains with slow growth rate consume relatively less nutrients in the same time.

However, strains with moderate growth rate have higher requirements for nutrients, but cannot compete with strains with stronger growth rate and moisture tolerance. If the nutrients are squeezed, the biomass of such fungi will be significantly reduced, and the possibility of population decline will be higher.

In regions with complex climate change, the interactions between populations are even more complex. When in a short period of time the weather volatility, has the high growth rate and narrower niche breadth of fungi amount will be affected by severe, at this time the number of fungi have lower growth rate and wider in the short term will rise, when the external environment to stability, and gradually return to the previous ones, according to the competition model described the relationship between the development.

5.2 The Survival Of Species In Various Environments

We then consider the survival of colonies in different environments, including arid, semi-arid, temperate, arboreal, and tropical rain forest. First, ambient temperature and humidity play a direct role in the growth of fungi.Dryness and hygroscopic conditions will affect the growth of fungi that are not suitable for the water niche.

Therefore, we speculate that the fungal diversity will be affected in the drought environment, and the strains with large water niche width will adapt to more climatic environment.Temperate, arboreal climates have favorable temperatures and humidity, which makes it easier for various fungi to survive.Tropical rainforests are more hospitable to fungi that are resistant to moisture and heat.

In addition, seasonal changes in precipitation will produce soil dry-wet alternation, which will promote and inhibit the quantity and activity of soil fungal organisms, and the colonies with large niche width will benefit from it.

On the other hand, carbon and nitrogen are indispensable elements for the growth of fungi, and soil carbon and nitrogen factors are greatly affected by hydrothermal conditions.According to "Effects of Decomposition of Dead Leaves of Typical Plants on Soil Organic Carbon and Nitrogen Transformation and Microbial Diversity in Loess Hilly Region"[12], "Decomposition of Dead Leaves and Roots of Plants can significantly increase soil organic carbon and nitrate nitrogen contents in 0-5cm and 5-15cm soils".It was found that the increase of soil bacteria and fungi was staged by dead leaves.In the early and middle stages, soil microorganisms are in a process of constant adjustment, so leaf litter can change soil microbial community structure and improve microbial community diversity at the same time.

In the later stage, under the action of litter, the number of fungi increases significantly, which plays a positive role in the survival and reproduction of fungi.In arid and semi-arid regions, vegetation is scarce, so the number of dead leaves which can improve fungal diversity is less than that in temperate and arbor regions.The variety of vegetation species in the tropical rain forest has improved the superior conditions for the growth and reproduction of fungi.

In addition, the influence of different plants on the fungal community is also very different.The paper "Dynamic Characteristics of Wetland Fungal Community Around

Onion Leaves" [12](National Plateau Wetland Research Center, Southwest Forestry University, 2019.2.17) studied the influence of aquatic plants on the structure of wetland fungal community.The results of sampling showed that the Alpha and Beta diversity of the fungal community was low, the community structure was simple, and the obligate attachment relationship of the fungal community on the surface was stable and the similarity was high.

In addition, it should be noted that microorganisms and vegetation may compete for nutrients under certain conditions.In "Changes of Soil Microbial Diversity at Different Altitudes in Wuyi Mountain"[12]. A large number of experiments and detailed analyses were made on the vegetation and fungal community structure at different altitudes.The paper points out that for the survival and reproduction of microorganisms, the temperature rises in spring, the activity of microorganisms increases, and the nutrients accumulated in autumn can be released instantly, which provides rich nutrients for fungi, and the number of fungi increases sharply.

Summer is the peak season for plant growth. Fungi and plants are in nutrient competition, and the nutrients available to bacteria are sharply reduced, resulting in insufficient growth substrates and a sharp decline in the number. In autumn, due to the input of dead leaves and the increase of substrate, the growth of fungi appeared the second exponential growth period.However, as the temperature drops, the growth of the fungus slows down.The lowest temperature in winter, microbial activity is inhibited, fungi in the dead or dormant state, most stop growth and reproduction, so the number of sharp decline.

Therefore, we can infer that the fungal community structure of tropical rain forest is relatively constant due to high temperature and rainy weather throughout the year, and is subject to little seasonal change.

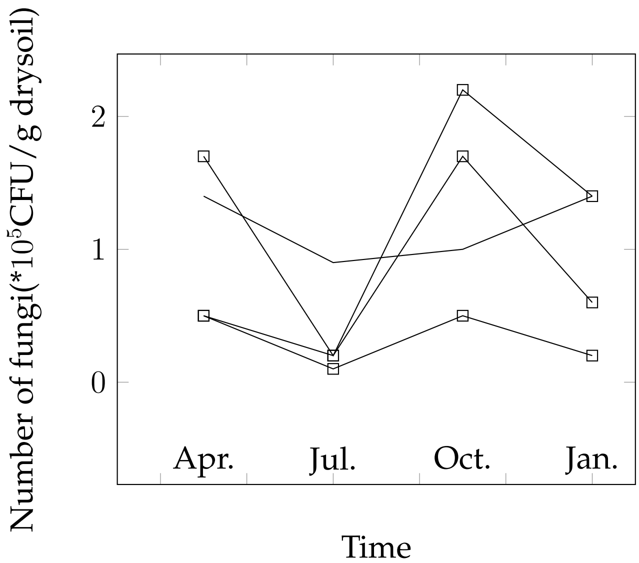

Figure 10: Seasonal dynamics of fungi in different soil layers

Table 2: Distribution of microbial quantity in soils at different altitudes in each month

Types of microorganisms	Time	Evergreen broadleaf forest	Coniferous forest	Subalpine Coppice	Alpine meadow
bacterial	Apr.	93.83Ba	100.03Bab	20.37ABa	221.33Aa
	Jul.	81.20Aab	111.07Aab	84. 80Aa	132.00Ab
	Oct.	115.67Aa	118.73Aa	60.33Aa	117.47Abc
	Jan.	34.19Ab	21.93Ab	47.90Aa	53.23Ac
Fungus	Apr.	0.69Aa	0.78Aa	0.24Ba	0.27Ba
	Jul.	1.08Aa	0.23ABa	0.23ABa	0.07Ba
	Oct.	0.47Aa	0.93Aa	0.56Aa	0.28Aa
	Jan.	0.64Aa	0.66Aa	0.25ABa	0.15Ba
Actinomycetes	Apr.	2.76Ab	2.02Ab	1.64Aa	1.54Ab
	Jul.	6.73Aab	2.40Cb	3.54BCa	5.26ABab
	Oct.	6.21Aab	4.20Aab	4.49Aa	5.06Aab
	Jan.	10.5Aa	6.02Aa	3.99Aa	8.39Aa
Total number of microorganisms	Apr.	97.32Aab	102.88Ba	122.22ABa	223.14Aa
	Jul.	88.99Aab	113.70Aa	88.65Aa	137.19Ab
	Oct.	122.50Aa	123.97Aa	65.36Aa	122.72Ab
	Jan.	45.75Ab	28.61Aa	52.15Aa	61.75Ab

6 Fungal Species Diversity And Ecological Protection

6.1 Relationship between fungal species diversity and carbon dioxide

We may always intuitively believe that the more biodiversity, the better, but it is not. If each kind of fungus is in a different niche, that is, different kinds of fungi are responsible for different steps in the process of decomposition, such a fungal population has a symbiotic relationship. In this case, the better the biodiversity is, the higher the decomposition rate will be.

The research of Chunyan Yang, Douglas A. Schaefer and others provides us with another idea. As we all know, the decomposition of nature will lead to the emission of carbon dioxide, and the annual emission of carbon dioxide is as much as that of fossil fuels. Therefore, if we understand the specific mechanism of biological decomposition, it will provide a powerful means for countries to deal with global warming. It was found that the decomposition rate of the experimental group with high fungal diversity was lower than that of the control group[5, 6, 7].

The diversity of fungi will have a negative impact on the decomposition rate. Therefore, increasing the species diversity of fungal community can effectively reduce the

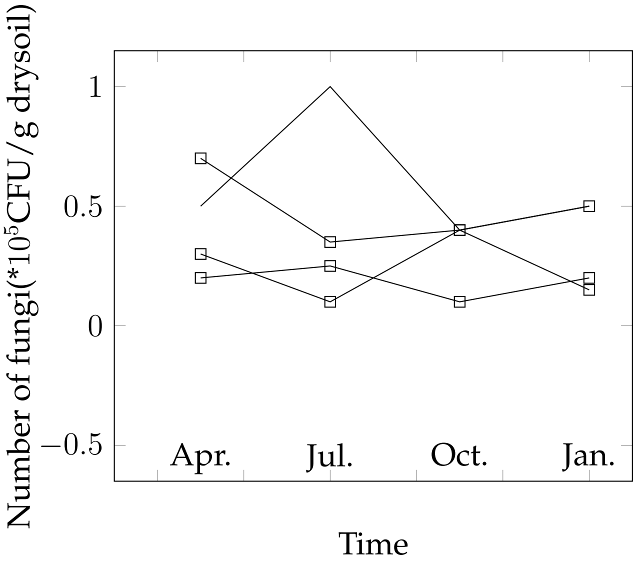

Figure 11: Seasonal dynamics of fungi in different soil layers

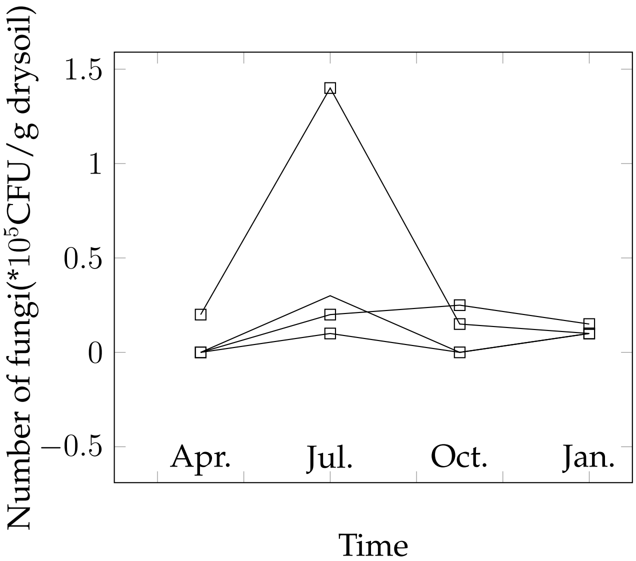

Figure 12: Seasonal dynamics of fungi in different soil layers

carbon dioxide emissions, and it is a meaningful action to reduce the carbon dioxide emissions of biological factors.

6.2 Model Simulation In Different Environments

When we use the model constructed by the third question to increase the number of fungal species, the substrate will be completely decomposed in a longer time. This similar result is consistent with the experimental results of many scientists.

We try to change the difference of environmental nutrients, such as adding a variety of nutrients in the model, then the simulation result is that the decomposition rate of high diversity fungal community has a certain degree of upward trend. This further verifies the correctness of our model.

6.3 Reasonable Explanation And Hypothesis

Although from the perspective of model results, the higher the species diversity of fungi, the lower the substrate decomposition rate. But we have to try to explain the mechanism behind this.

1. This may be due to the pure diversity effect. When the richness and evenness of fungi increase, it may slow down the decomposition rate of substrates, regardless of the species of fungi.

2. Another possible reason is species selection. Species diversity of fungal community may lead to competitive advantage of fungal species with slow decomposition, thus slowing down the decomposition rate of fungal community.

3. Through consulting the data, it was found that the higher the diversity of microorganisms, the higher the decomposition rate of soil organic matter[8, 9]. This may be because the organic matter in soil is more than that in wood substrate, and the niche complementarity between microorganisms drives the positive correlation between diversity and organic matter. We can assume that the niche overlap of fungi will lead to limited nutrient competition, which can be observed in many forests[10]. It is this phenomenon that reduces the decomposition rate of substrate.

7 Two-page Article

The New Research on the Roles Fungi Play in Ecological Systems

What's the the problem background and why fungi?

My honourable young readers, as we know ,carbon cycle describes the continuous exchange and movement of carbon on the earth.And in the carbon cycle process, the decomposition of organic material plays important role,which updates and changes the existing form of carbon.In this process ,especially the degradation of plant material and woody fibers involving fungi, is an essential link.

Recently The author of a recent paper which researches on the decomposition wood by fungi has pointed out the fungal characters that determine the decomposition rate, and figured out the relationships between some characters. Particularly, slow growing fungal strains can survive and grow better in the presence of environmental changes.

In this problem,we only consider two traits of fungi——growth rate and moisture resistance.Our main goal is to model the decomposition of wood fibers on a given land and in the presence of multiple types of fungi that decompose wood fibers in the fixed area.

Thus it's essential to study the roles fungi play in ecological systems!

What's our work?

To show you our conclusion better, let's talk about our work first!

Briefly,our work can be generalized into five parts as follows:

1. According to the data provided by the data set, multiple linear regression analysis was conducted between the decomposition rate of lignin fiber and the factors that might be related to it.
2. Firstly,we initially use regression analysis to establish a multiple linear regression model of the decomposition rate of wood fiber .And established a mathematical model of the growth rate.
3. Secondly,we use K-Means algorithm to incorporate the interactions between different species of fungi which has different traits.Analyse the interactions between different types. Optimize and verify the growth rate model.
4. Thirdly,we analyse the dynamics of the interactions and examine the sensitivity to rapid fluctuations.
5. Then,we predict the relative strengths and weaknesses of each species and its possible persistent species combination and apply to five different environments.
6. Finally,we describe how the diversity of fungal communities of a system impacts the overall efficiency of a system with respect to the decomposition of the ground litter.

Predict the importance and role of biodiversity in the varying degrees of variability in the local environment. (For more details,you can read our solutions.)

What's our new findings and conclusion?

Fungi with a high growth rate and moisture tolerance are more likely to survive when the environment is relatively stable.While when the weather is changeable,fungi with a large water niche width are more competent.We also further discussed the dependence between fungi and the environment and found out the possible seasonal changes of fungi in different areas.

Our model successfully shows the relationship between fungal species diversity and decomposition rate. When the fungal species diversity is higher, the decomposition rate will also decrease. Because decomposition will emit carbon dioxide, it also indirectly implies the relationship between species diversity and carbon dioxide. It has positive significance for environmental issues related to greenhouse gas emission reduction, and is helpful to optimize the global carbon cycle and co-build a beautiful earth!

Thanks,my honourable young readers!

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