Problem Chosen	2021 MCM/ICM Summary Sheet	Team Control Number
A		**2103179**

Fun in fungi: Wood Decomposition by Fungi

Summary

As fungi are some of the key agents in decomposing woody fibers, studying traits of fungi is helpful for us to learn more about the breakdown of lignocellulosic fibers. Among the many characteristics of fungi, fungi's tolerance to moisture and growth rate play crucial role in decomposing fibers. In particular, with changing of moisture and temperature where fungi live, the growth rate of fungi will alter. Therefore, it is our goal to construct a model of fungi's decomposing fibers with respect to their own traits and the environment.

To accomplish our missions, we establish 4 sub-models as follows:

- **Fungus Decomposition Rate Model**: We assume the wood decomposition and the total amount of fungi in the environment will affect the growth rate of fungi. At the same time, we also consider the effect of fungal growth rate and moisture tolerance on the fungal decomposition rate. So we establish a dynamical system model.
- **Optimization of Fungus Decomposition Rate Model**: In the optimization, we assume the interaction between different types of fungi, which makes our model look more in line with the laws of nature.
- **Ideal Growth Rate Model**: The relationship between ideal growth rate and temperature and humidity obeys the mixed Gaussian distribution. Therefore, with the help of mixed Gaussian distribution, we establish a model of the relationship between climate and growth rate.
- **Decomposition Prediction of Fungi Combination**: Using competitive ranking to combinate fungi, we get fungal decomposition rate curves in different environments, including arid,semi-arid, temperate, arboreal and tropical rain.

We analyze the results of each of these models, performing sensitivity analyses on the input parameters and demonstrating their flexibility.

Finally, our model shows that rapid environmental fluctuations will affect the growth rate and the decomposition rate of fungi. In the long run, the influence of climate fluctuations become oblivious. Besides, in tropical rain forests,the performance of fungi's decomposing woody fibers is better than that in other four environments. Furthermore,the better the species diversity of fungi combination, the more able to adapt to different environments, which also reflects the importance of species diversity to the ecological environment.

Keywords: Difference equation; Gaussian distribution; Decomposition Rate; Growth Rate

Contents

1 Introduction

1.1 Overview

Carbon cycle, the foundation of life, describes the exchange process of carbon throughout the geochemical cycle. A key component of the carbon cycle is the decomposition of plant material and wood fibers. In a paper on the decomposition of wood, the researchers examined a large number of traits associated with different fungi and their role in the decomposition of ground litter (dead plant material) and woody fibers. These conclusions are the biological theoretical foundations of our research and modeling.

In order to study the role of fungi in biological systems better, we need to describe the process by which fungi decompose wood fibers when multiple fungi exist and interact with each other. We also need to answer some questions, such as "Using these two traits, how do the different fungi interact and decompose ground litter in a fixed patch of land in differenenvironments?","Within these different environments, how will the decomposition be impacted over time as conditions vary?" and "How do environmental changes and the variation in environmental change impact the long-term dynamics with respect to decomposition, as well as competition between fungi in a given environment".

In order to solve a series of mathematical models for fungi decomposing wood fiber, we described the relevant biological mechanism, mathematical modeling, realization and results in the article, then evaluated the sensitivity of the results. Finally, we introduced the advantages and disadvantages of our model.

1.2 Simplifying Assumptions

- Only 20 fungi from North America are considered in our discussion.
- Decomposition rate is only affected by fungal growth rate and moisture tolerance.
- Natural resources (decomposed wood) are limited.
- Only biological interactions of different fungi are considered interspecies competition.
- The relationship between ideal fungal growth rate, temperature and humidity obeys mixed Gaussian distribution.
- Fungi at high competitive ranking won't coexist peacefully with fungi at low ranking. Otherwise, the latter would die out due to excessive interspecific competition.
- We ignore the influence of other biological or non-biological factors where fungus live, expect for temperature and moisture.

1.3 Variable description

Table 1: Variable description

Variable	Statement
t	time (days)
d_i	Rate of decomposition rate at time t
x_i	The number of the i-th fungus
$x_i{}^*$	Environmental capacity of the i-th fungus
r_i	Growth rate of the i-th fungus
$r_i{}^*$	Ideal Growth rate of the i-th fungus
m_i	Mositure Trade-off of the i-th fungus
y	The amount of wood decomposed at time t
y^*	Total amount of wood
y/y^*	Decomposition rate (%)
α	Influencing factors of interspecific competition on Growth rate
β	The influence factor of interspecific competition on decomposition rate
c_i	Competitve ranking of the i-th fungus
tmp	Temperature (°C)
mois	moisture (mPa)

2 The Fungus Decomposition Rate Model

2.1 Theory

We suppose that there are many kinds of fungi in this environment, but they have no interactions. The decomposition of wood in the environment is shown in Figure 1:

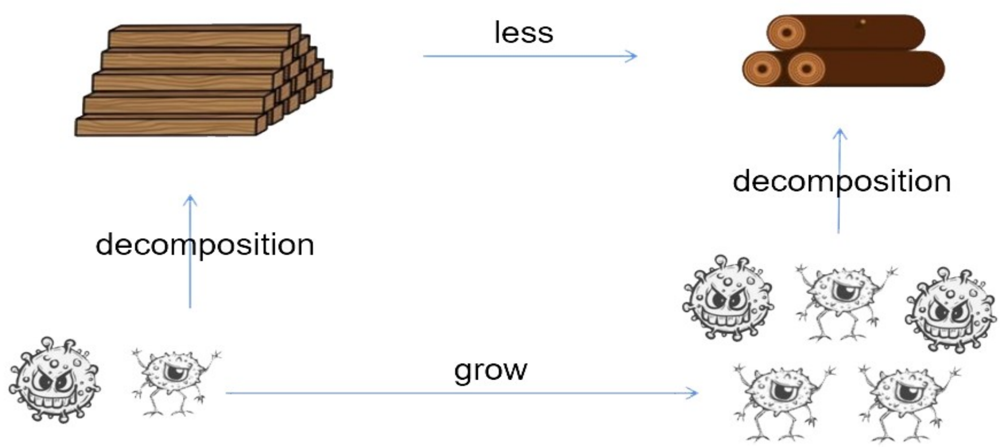


Fig. 1. Schematic diagram of wood decomposition of various fungi without interactions

The growth rate of the fungus will be affected by the total amount of fungi and decomposition of the wood. The more wood is decomposed, the less it remain, which is needed during the growth of the fungus. If the nutrients become less, the growth rate will be slower. Similarly, when the total amount of fungi is larger, the remaining amount of fungi that the environment can hold will be less, and the growth rate of fungi will be slower. Therefore, we construct equation (1):

$$r_i = (1 - \frac{y}{y^*})(1 - \frac{x}{x^*})r_i^* \tag{1}$$

In this article, we only discuss the effects of fungal growth rate and moisture tolerance on fungal decomposition rate. Therefore, for the decomposition rate of the i-th fungus at time t, we set a_i and b_i as the influence factor of fungal growth rate and moisture tolerance. According to the paper [1], it can be obtained that the logarithm of water tolerance and decomposition rate has a linear fitting relationship. So the exponential linear relationship between decomposition rate and water tolerance will be stronger.

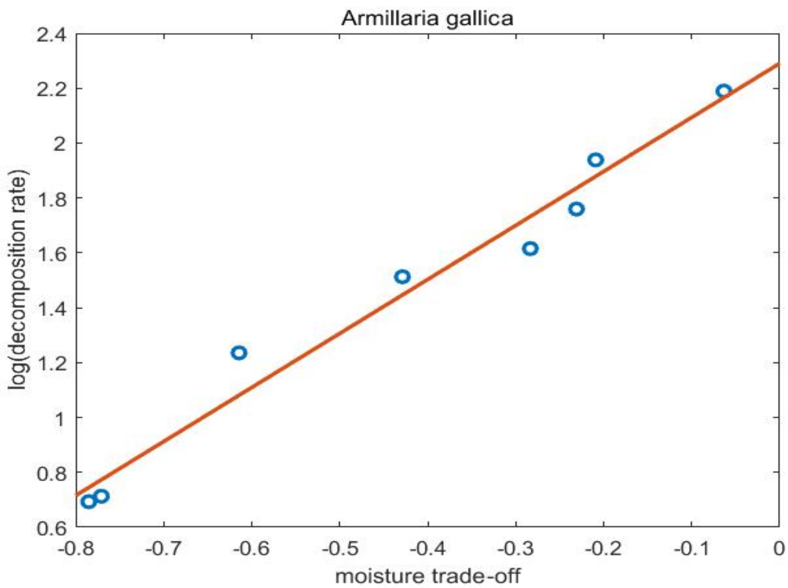


Fig. 2. The relationship between water tolerance and logarithm of decomposition rate

At the same time, the remaining amount of wood also affects the decomposition rate of fungi. So we get equation (2):

$$d_i = (a_i r_i + b_i e^{m_i})(1 - \frac{y}{y^*}) \tag{2}$$

The amount of decomposition is actually the sum of the product of the decomposition rate and the total amount of fungi at every moment before, so formula (3) is obtained:

$$y = \int \sum_i d_i x_i dt \tag{3}$$

Therefore,our initial model of fungal decomposition rate is established as follows:

$$\begin{cases} r_i = (1 - \frac{y}{y^*})(1 - \frac{x}{x^*})r_i^* \\ d_i = (a_i r_i + b_i e^{m_i})(1 - \frac{y}{y^*}) \\ y = \int \sum_i d_i x_i dt \end{cases}$$

2.2 Implementation and results

MATLAB is used to implement the three equations of the theoretical part. In order to determine the values of the unknown parameters a and b, we use the 122-day data from the laboratory results of the paper [2] as the known quantity. The decomposition rate curve of 20 kinds of fungi in a certain place with time is obtained as shown in Figure 3.

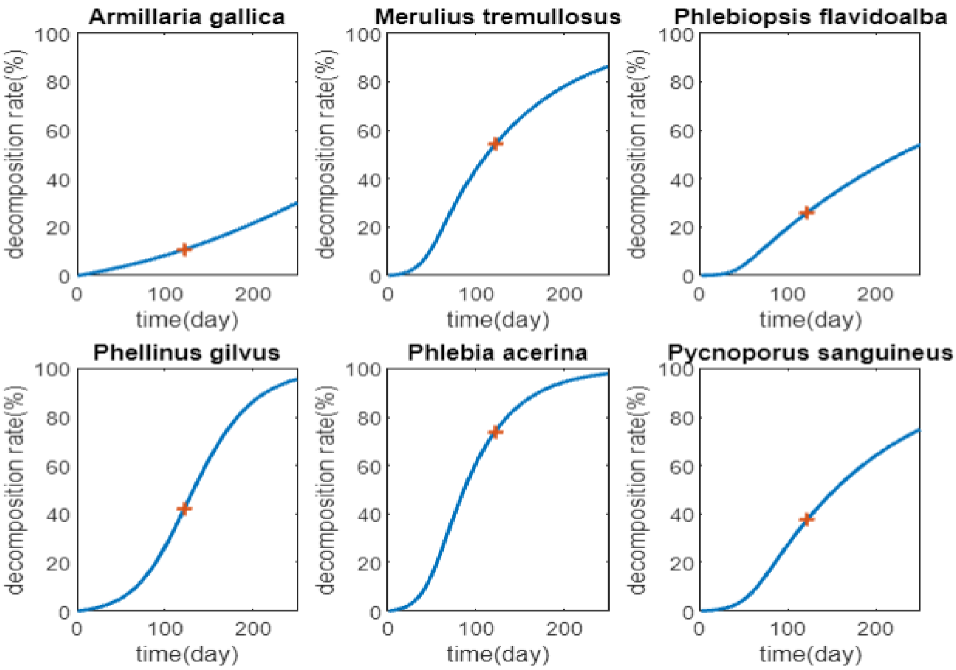


Fig. 3. Graph of decomposition rate over time

The abscissa of each curve in the figure is time, and the ordinate is the resolution rate. In the analysis, we select 0.1 as the interval length to divide the fungal decomposition rate interval [0.1, 0.7] on the 122nd day into six intervals, then look for a fungus that can be a typical representative in each interval. We decompose the rate curve in the figure 3 above. The red dot shown in the figure is the decomposition rate of the fungus on day 122.

These six typical curves are roughly in the shape of "S", from which we can learn that the fungus decomposes very quickly in the local environment. However, as time goes by, the fungal reproduction in the environment increases the total amount of fungi, leading to the decrease of the amount of undecomposed wood. These changes all cause the decomposition of fungi to slow down, and the increase in decomposition rate becomes smaller.

In the end,this model is too simple to consider the mutual influence of different types of fungi growing in the same environment, but the qualitative results here serve as a good basis for subsequent models. At the same time, in this qualitative result, we select 6 representative fungi among the 20 fungi based on the decomposition rate−−Armillaria_gallica,Merulius_tremullosus, Phlebiopsis_flavidoalba, Phlebia_gilvus,Phlebia_acerina,Pycnoporus_sanguineus.These six fungi will be given as a representative when we make the analysis of single fungus.

3 Optimization of Fungus Decomposition Rate Model

3.1 Theory

Different kinds of fungi have different growth rates and moisture tolerance. When they live in the same environment, they will inevitably have a competitive relationship with food and living environment. Therefore, discussion of the interspecific competition between different species of fungi is added to the analysis. The decomposition process in the ecological environment is shown in Figure 4.

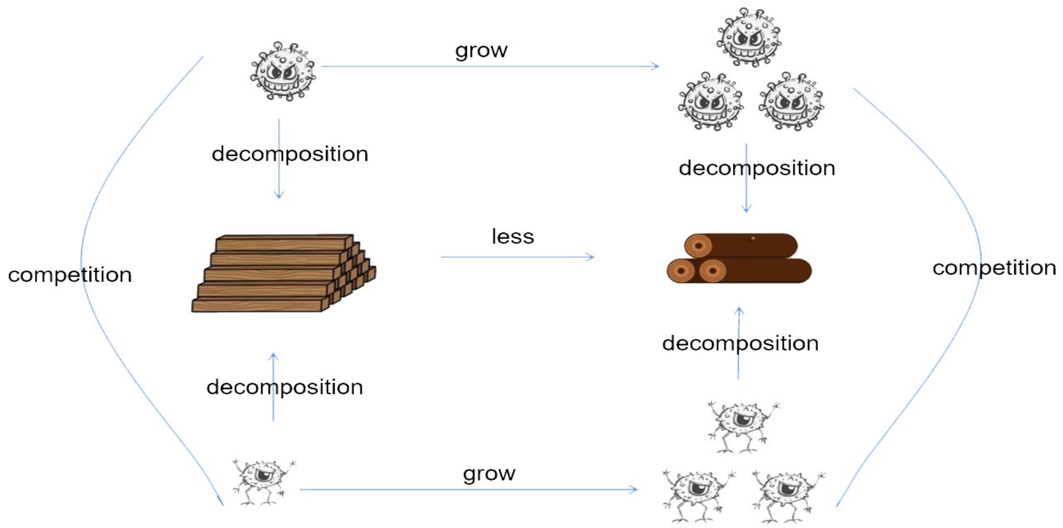


Fig. 4. Schematic diagram of wood decomposition when various fungi interact with each other

For the fungi we discussing, their competitive ability in the same environment is different. We set the competition ranking of the i-th fungus as c_i and calculate the competitiveness of these fungi as shown in Figure 5.

Fig. 5. Competitive ranking for Fungi

For formula (1), we set α as the influence factor of inter-species competition on the growth rate. Therefore, the existence of each other fungus in the environment will have a negative impact on the growth rate of the ith fungus. Moreover, we take biodiversity into account. So when calculating the competitive pressure of species diversity, we set the sum of the competitiveness of all species $\sum_k c_k x_k$ to be the denominator, and $\alpha \frac{\sum_{j\neq i} c_j x_j}{\sum_k c_k x_k}$ to be the competitive pressure of the i-th fungi. Therefore, we changed the formula (1) to (4).

$$r_i = (1 - \frac{y}{y^*})(1 - \frac{x}{x^*})r_i^* - \alpha \frac{\sum_{j\neq i} c_j x_j}{\sum_k c_k x_k} \tag{4}$$

For equation (2), we set β as the influence factor of interspecific competition on the decomposition rate. Similarly, when calculating the final decomposition rate, we also consider the negative impact from each other fungus to the i-th fungus. So we change the formula (2) to (5).

$$d_i = (a_i r_i + b_i e^{m_i} - \beta \frac{\sum_{j\neq i} c_j x_j}{\sum_k c_k x_k})(1 - \frac{y}{y^*}) \tag{5}$$

Equation (3) has not changed, and applying equations (1) and (2) to MATLAB, we can get a suitable answer.

$$y = \int \sum_i d_i x_i dt \tag{6}$$

Therefore, when we consider the interaction between fungi, the model is optimized to the following formula:

$$\begin{cases} r_i = (1 - \frac{y}{y^*})(1 - \frac{x}{x^*})r_i^* - \alpha \frac{\sum_{j\neq i} c_j x_j}{\sum_k c_k x_k} \\ d_i = (a_i r_i + b_i e^{m_i} - \beta \frac{\sum_{j\neq i} c_j x_j}{\sum_k c_k x_k})(1 - \frac{y}{y^*}) \\ y = \int \sum_i d_i x_i dt \end{cases}$$

3.2 Selected fungi combinations

We make a hypothesis that fungi with higher competitiveness will be relatively easier to inhibit the growth of fungi with low competitiveness, and even lead to the complete extinction of fungi with low competitiveness in this environment when they growing in the same environment at the same time.

To show that our hypothesis is reasonable, we selected two fungi, one is Merulius_tremellosus whose competition ranking is in the interval [0.7, 0.8], and the other one is Armillaria_gallica whose competition ranking is in the interval [0, 0.2]. Assuming that only Merulius_tremellosus and Armillaria_gallica are in the environment, we use our model to make the growth curves of these two fungi as shown in Figure 6.

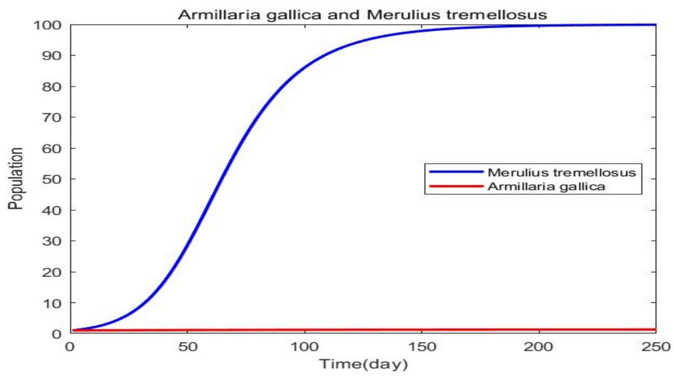


Fig. 6. Growth curve of two fungi

Figure 6 shows that our hypothesis can be established. Therefore, in order to make the species in the growth environment diverse, we put the fungi with similar competitiveness in a combination when we combined the 20 fungi species. According to Figure 5 (the competitiveness ranking of the 20 fungi), the fungi are divided into five groups as shown in Figure 7.

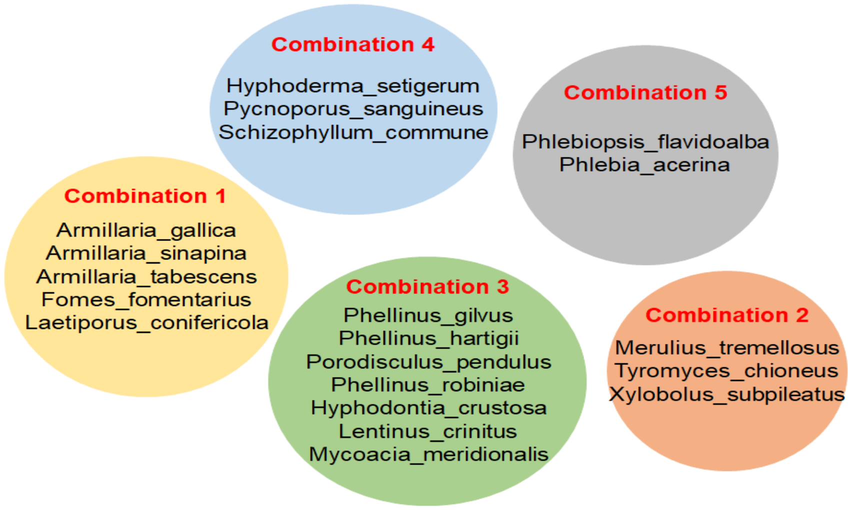


Fig. 7. Fungi grouping diagram

4 Ideal Growth Rate Model

4.1 Math preparation

The Gaussian distribution, known as the normal distribution, is a probability distribution that is very important in the fields of mathematics, physics, and engineering. And the distribution has a significant influence in many aspects of statistics. If a random variable obeys the probability distribution of a position parameter and a scale parameter, it is recorded as–its probability density function is the mathematical expected value of the normal distribution or the expected value is equal to the position parameter, which determines the location of the distribution. The square root or standard deviation of its variance is equal to the scale parameter determines the extent of the distribution. The main formula is:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-(x-\mu)^2}{2\sigma^2}} \tag{7}$$

In the formula, the first parameter μ is the mean value of a random variable following a normal distribution, and the second parameter σ^2 is the variance of this random variable. The probability law of a random variable that follows a normal distribution is that the probability of taking a value close to μ is greater, and the probability of taking a value farther from μ is smaller. The smaller the σ is, the more concentrated the distribution is near μ; the larger the σ is, the more the distribution dispersion.

4.2 Theory

According to the paper [1], under standardized laboratory conditions,we can have the data measured at 10, 16 and 22°C for the decomposition rate of each isolate. We assume that the relationship between the ideal growth rate, temperature and moisture obeys the mixed Gaussian distribution for which is common existence in nature. At the same time, assuming that other conditions are constant and only the temperature is changed, the temperature at which most fungi growth rate reaches the maximum is 22 degrees Celsius. Since temperature and moisture affect the ideal growth rate, we replace r_i^* with $r_{i,t}^*$ to be the variable of the ideal growth rate over time. We list the equation of the mixed Gaussian distribution as

$$r_{i,t}^*(tmp, mois) = p_1 e^{-\frac{(tmp-l_1)^2}{q_1^2}} + p_2 e^{-\frac{(mois-l_2)^2}{q_2^2}} \tag{8}$$

In order to analyze the sensitivity of fungal growth and wood decomposition to rapid environmental fluctuations better, we need to select data from places where rapid environmental fluctuations occur within a certain period of time for research, which can make our research results more credible. Analyzing the temperature and humidity data of Amazon in 2020, which is mainly the tropical rain forests climate, we get the following figure.

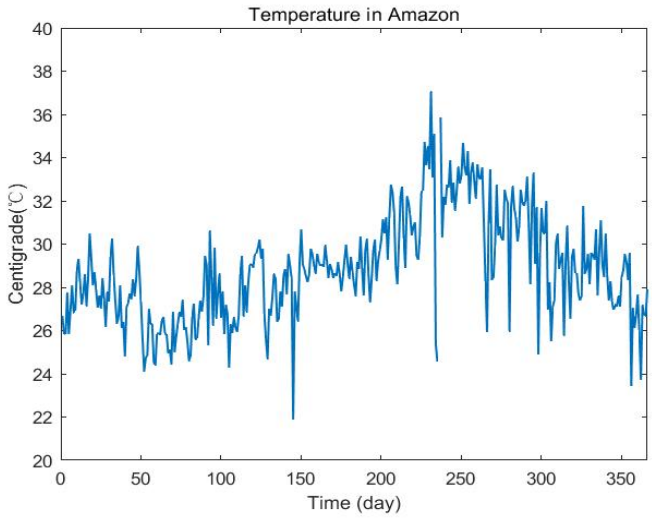


Fig. 8. Temperature data analysis graph of tropical rain forest climate

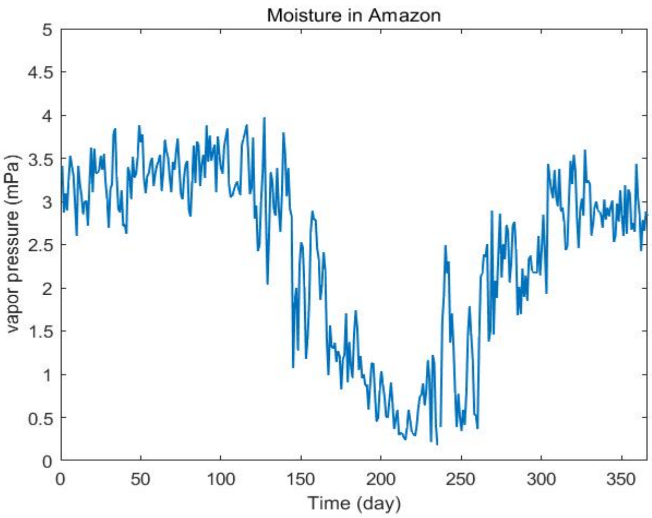


Fig. 9. Moisture data analysis diagram of tropical rain forest climate

From Figure 8 and Figure 9, it is clear that the temperature and water niche have rapid fluctuations throughout the year, which meets the data conditions we need. Therefore, we take the data until the 250-th day as the short-term data,and the whole data as long-term data. The interaction trends of different types of combinations under short-term and long-term atmospheric changes are studied separately.

4.3 Implementation and results

Using our model and the data of Amazon's temperature and moisture, we make the decomposition rate image of the five fungal combinations.

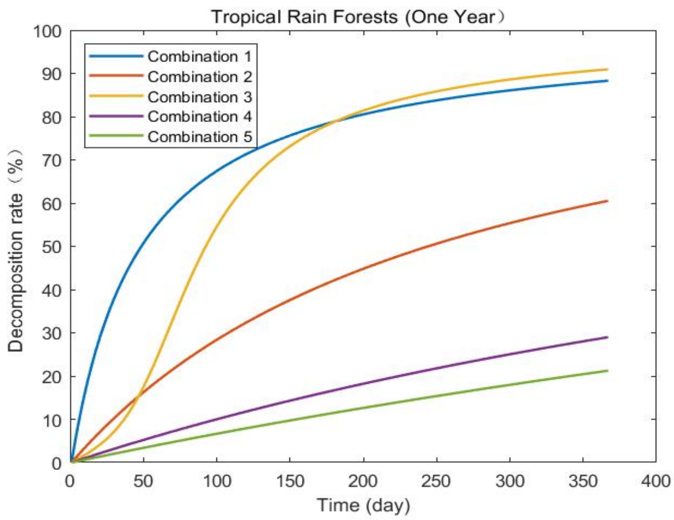


Fig. 10. One-year decomposition rate curve diagram of five combinations

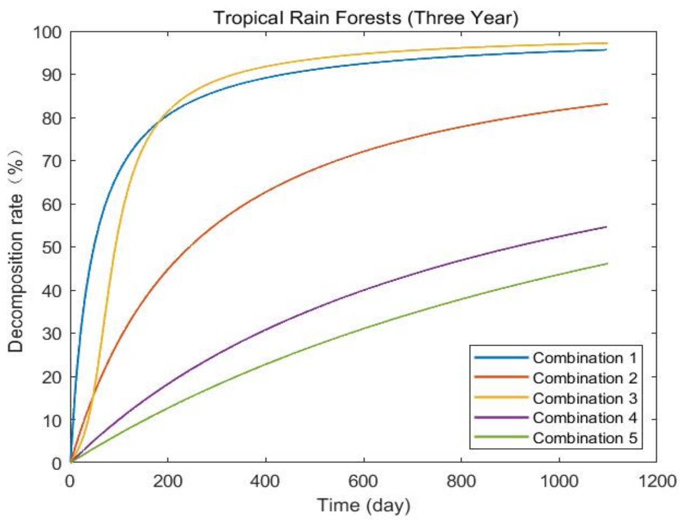


Fig. 11. Three-year decomposition rate curve diagram of five combinations

We can find the curve shape of combination 3 is the closest one to the "S" shape in the one-year and three-year curve, so we mainly use combination 3 as a representative for analysis in the following discussion.

We differentiate the decomposition rate for one year, and obtaine the change rate of the decomposition rate of combination 3 in each day.

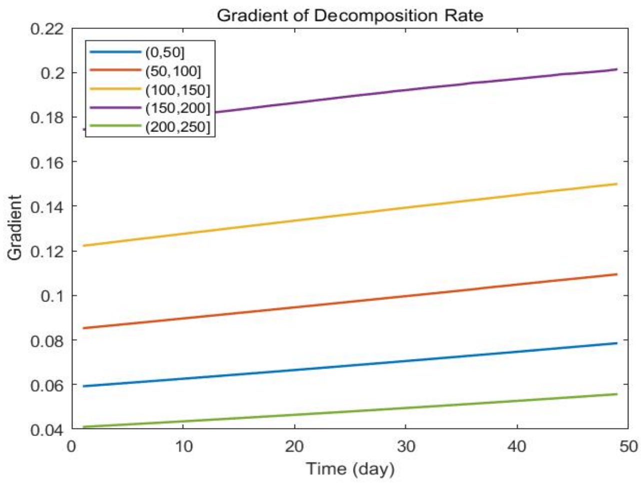


Fig. 12. Combination 3 Decomposition rate change rate curve every 50 days

We assume that the local environment and the number of fungi will return to the beginning every 50 days, so that we can eliminate some irrelevant factors such as the environmental capacity of fungi and the impact of the total amount of wood remaining on the decomposition rate.

By reading the paper [1], we can know that the most suitable temperature for growth and decomposition of most fungi is 22℃, and the most suitable humidity range is 1mpa to 1.5mpa. Comparing the temperature and humidity curves in Fig.12 with Fig.8 and Fig.9, we find that the decomposition rate is very low due to the excessive dryness and high temperature when the temperature and humidity are in the interval shown in the 200-250th day. As the temperature and humidity gradually approach the most suitable conditions, the decomposition rate is slowly increasing. While observing the curve of days from 150 to 200, we found that though the temperature increased during this time, the effect of humidity on the decomposition rate of fungi was slightly greater than that of temperature, so the decomposition rate during this time remained at a very high level. In long-term climate change, due to the strong coordination and adaptability of the entire decomposition system, the decomposition rate curve will not produce much fluctuation.

It is shown that short-term climate fluctuations will cause the decomposition rate of fungi to fluctuate, and moisture will have a greater impact on the decomposition rate. In long-term climate fluctuations, as the increased influence of other factors, the influence of climate on the decomposition rate of fungi will become smaller and smaller.

5 Decomposition Prediction of Fungi Combination

5.1 Theory

In order to solve the relative advantages and disadvantages of predicting each species and the combination of species that may continue to exist in different environments well, we select a representative region for each environment and use the data for 2020 corresponding to the representative of the region analysis of climate and environmental data. We choose Egypt to represent the arid climate, Kenya to represent the semi-arid climate, Chicago to represent the temperate climate, Australia to represent the arboreal environment, and the Amazon to represent the tropical rain forest.

Fig. 13. Regional Representative Map

The source of the data for these five regions is the National Weather Service website (NOAA), but some of them are missing. We calculate the missing part of the data through linear interpolation (that is, the interpolation method using a linear function as the interpolation function), and finally get five all the data of each region in 2020 are substituted into the model for calculation.

5.2 Implementation and results

Using the data of these five regions, we make a graph of the decomposition rate of five species and six fungi in one year.

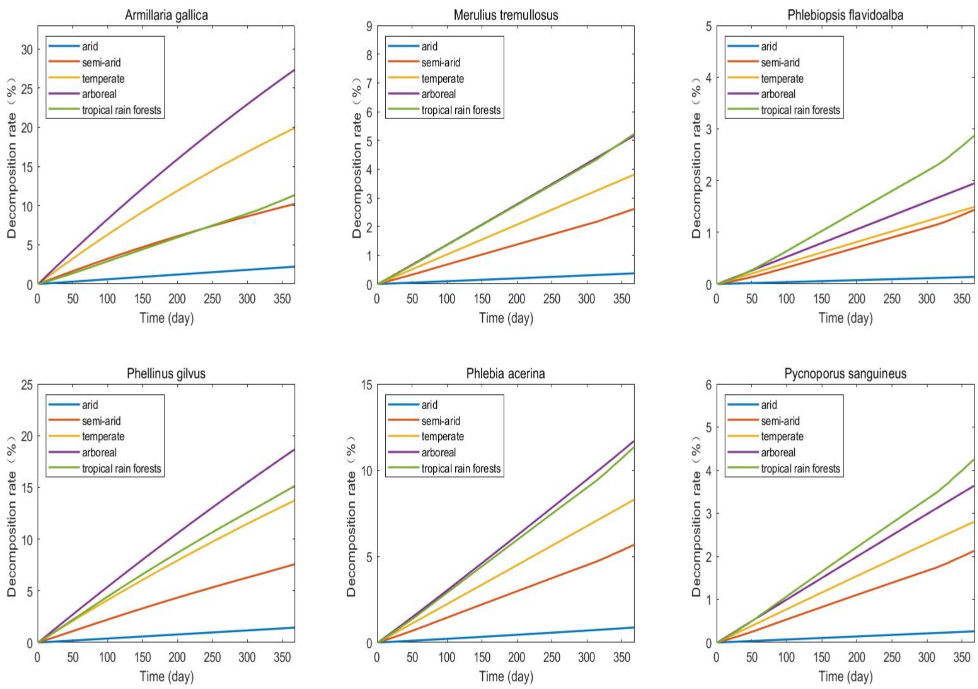


Fig. 14. One-year decomposition rate curve diagram of six fungi

From Figure 14 we find that all fungi survive and decompose poorly in arid environments. Most fungi have better decomposing ability in tropical rainforest and arboreal environment. Among all fungi, Aemillaria gallica and Phellinus gilvus have the best decomposing ability in arboreal environment. The decomposition ability of Merulius tremullosus, Phlebiopsis flavidoalba and Pycnoporus sanguineus in various climates are not particularly ideal.

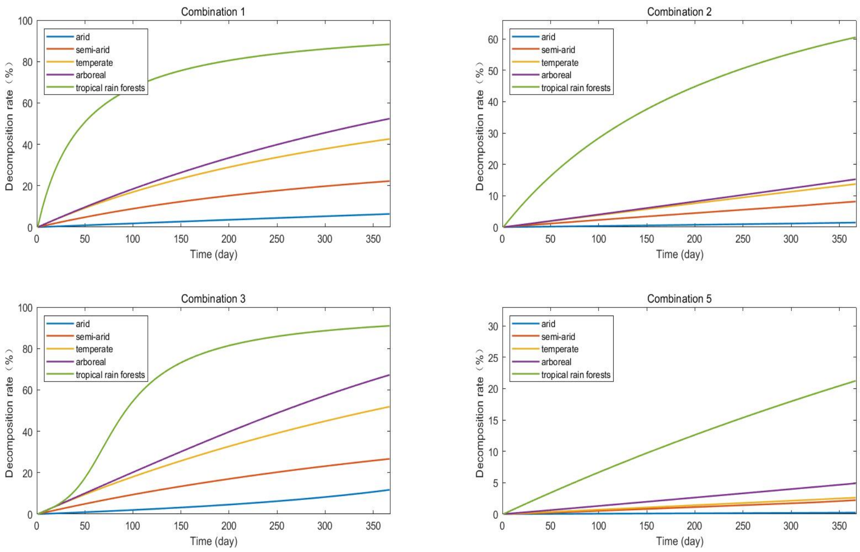


Fig. 15. One-year decomposition rate curve diagram of four combinations

Only four combinations are shown here because the number of fungal species in combination 2 and combination 4 are the same, and their performance under five climatic conditions are also the same. So in Figure 15, we use combination 2 as the representative of the performance situation of combination 2 and combination 4. From Figure 15, we learn that each combination can show good decomposition rate in tropical rain forest climate. The arid climate is very unsuitable for the survival of fungi, resulting in the low decomposition rate of the five combinations of fungi in this climate. We also find that the decomposition performance of combination 3 in various climates is better than the performance of the other 4 combinations.

Combining the decomposition rate curves of four combinations and six fungi in five climates, it is shown that Aemillaria gallica belongs to combination 1 and and Phellinus gilvus belongs to combination 3. Moreover, the decomposition rates of combination 1 and combination 3 are better than that of other combinations. Therefore, the decomposition ability of each fungus will directly affect that of the fungus combination. However, we also find that due to the existence of competition between species in different environments, fungi may not be able to fully display their decomposition ability, which also makes our final combined decomposition rate show the different situation with that of single fungus.

Nevertheless, our best combination of fungi under different climatic conditions is still combination 3.

6 The importance of biodiversity

In the previous article, we used five regions as representatives to calculate the decomposition rate curves of different fungal combinations under five climatic conditions. From the analysis of Figure 8 and Figure 9 above, it can be found that the climate of the tropical rain forest throughout the year fluctuates to varying degrees, which meets the prerequisites of our analysis. Therefore, in order to better answer this question, the decomposition rate curve diagram of each fungus combination is used as a representative to analyze in the most typical tropical rain forest climate.

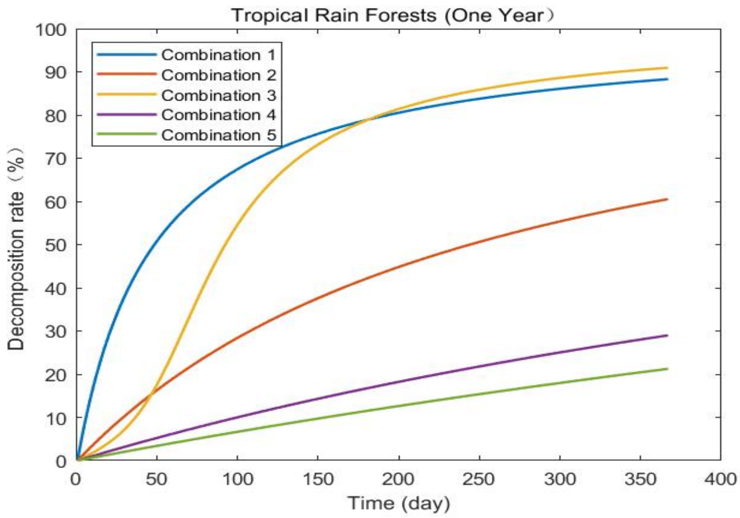


Fig. 16. Curve of annual decomposition rate of five combinations in tropical rain forest climate

We learn that the decomposition rate of combination 1 rises faster at the beginning from figure 16, followed by combination 3. There are 5 kinds of fungi in combination 1 and 7 kinds in combination 3. These two combinations have more fungal species than other combinations, and their decomposing ability in the early growth stage is also better. When time passed by the second half of the year, the decomposition rate of combination 3 gradually exceeded that of combination 1, that better reflect the importance of species diversity to the environment. When the total amount of each fungus gradually reaches the environmental capacity, there are more species, resulting to the stronger competition between species will be. And it will be easier to promote the efforts of species to grab food so that the decomposition rate can maintain a certain degree of increase.

In fact, the temperature and moisture of the tropical rainforest climate fluctuate to a certain degree throughout the year, and the diversity of species effectively helps the ecological environment to adjust more quickly according to environmental fluctuations so that the ecological environment will not collapse due to environmental changes. Moreover, when all aspects of the environment are gradually reaching their peaks, biodiversity helps the ecosystem to operate in an orderly manner. In terms of decomposing ground garbage, the diversity of fungal communities can maximize the competition between species and improve the overall efficiency of system decomposition.

7 Sensitivity Analysis

In the model, the fungal decomposition rate is affected by the influence factor "a" of growth rate and the influence factor "b" of humidity tolerance. In order to discuss whether the small changes of a and b have a significant effect on the curve of decomposition rate with time, sensitivity analysis is needed here.

Firstly considering the case of a single fungus, we make a and b deviations of 10% respectively. And the curves of the decomposition rate are plotted for Armiliaria_gallica, Pycnoporus_sanguineus, Phlebia_acerina and Merulius_tremullosus.

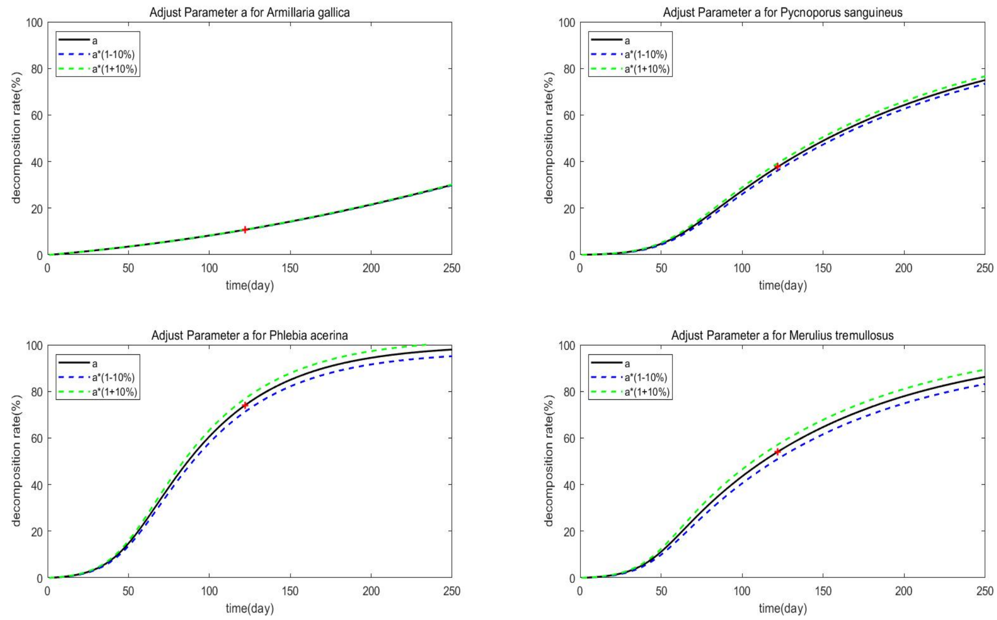


Fig. 17. Sensitivity curves of four fungi with respect to a

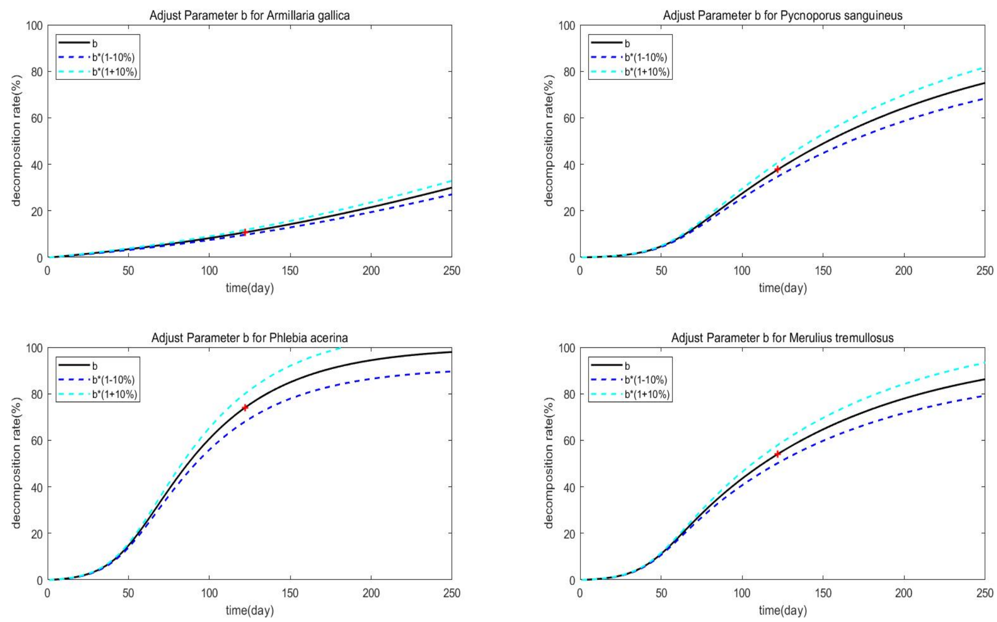


Fig. 18. Sensitivity curves of four fungi with respect to b

Secondly, considering the combination of fungi, four fungal combinations are selected . We also make a 10% deviation of a and b respectively, and plot the decomposition rate as a function of time for the four combinations as shown in the figure 19 and figure 20.

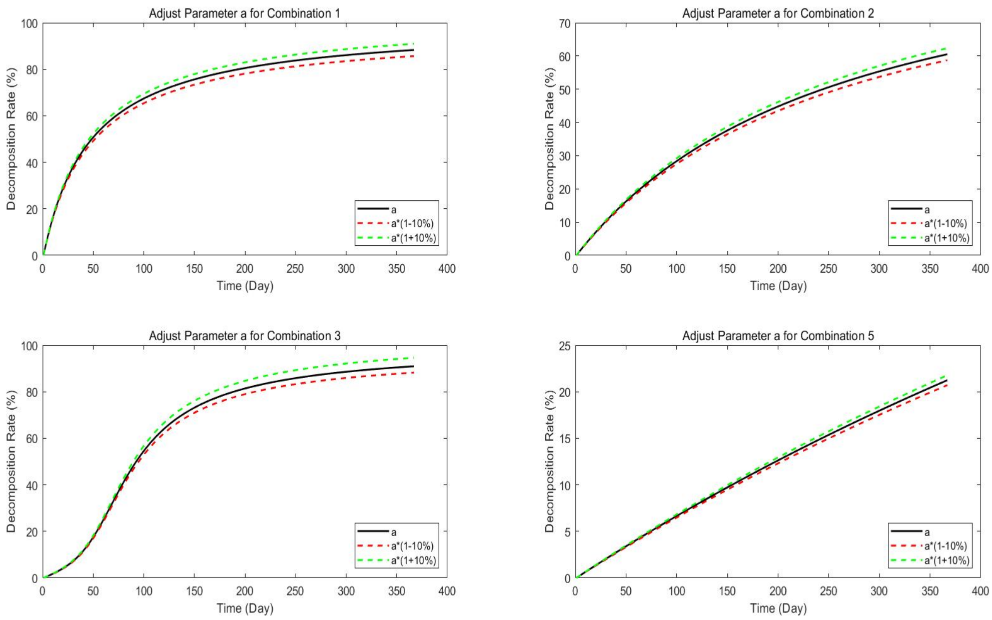


Fig. 19. Sensitivity curve of four combinations with respect to a

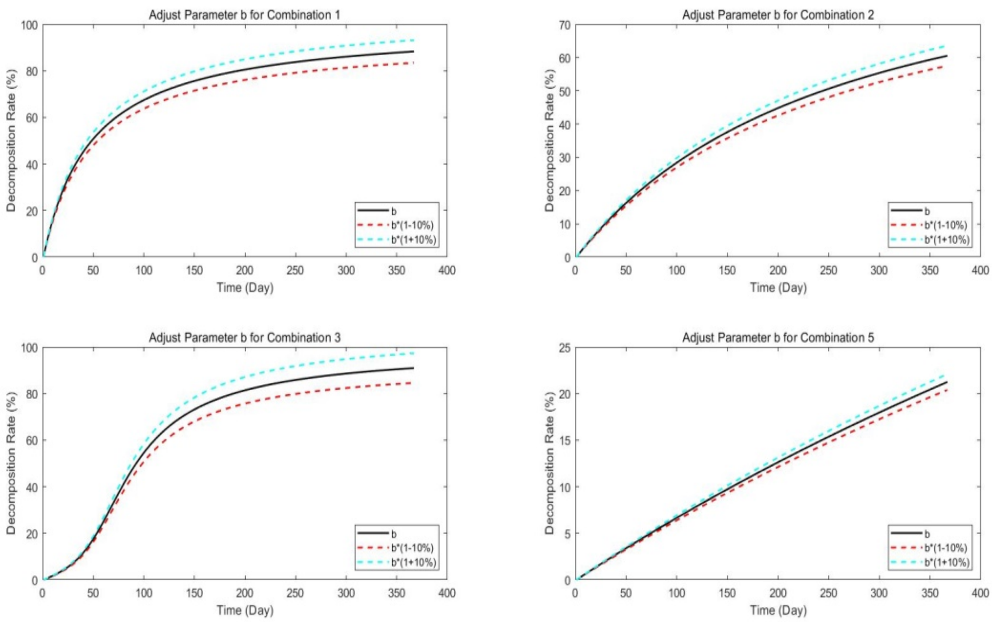


Fig. 20. Sensitivity curve of four combinations with respect to b

It can be seen from the figure that the change trend of the decomposition rate of a and b is basically the same with a deviation of 10% for fungus and fungi combination:

At each moment, the increase of a and b will cause the decomposition rate to increase, and the decrease of a and b will lead to the decrease of the decomposition rate. Secondly, different fungi or fungal combinations have different sensitivity to a and b. For example, among the four fungi we selected, Phlebia_acerina has the highest sensitivity, while Armiliaia_gallica has the lowest sensitivity. In addition, a longitudinal comparison of a and b shows that for a 10% deviation, the decomposition rate caused by b changes more, so b has a greater sensitivity to the decomposition rate. In other cases,the annual fluctuation range of the result is much smaller than the variable change,which indicates the stability of our model.

8 Strengths and Weaknesses

We have done lots of data processing, and use the principles of differential equations and Gaussian distribution to build a model that can solve the problem. Like any model, our models have strengths and weaknesses.

Strengths

- The model is universally applicable, which can be generalized to describe the competition of multiple organisms and the interaction with the environment
- Gaussian distribution exists so widely in nature that using Gaussian distribution to establish the rate decision model makes our results more in line with reality.
- Our model is formulated on a certain theoretical basis. After consulting a lot of literature, we carefully selected the parameters of the model. In this way, we can make our model as close to reality as possible.
- Computational complexity is small: the time complexity changes linearly with the increase of the number of days, which has a certain scalability. So this model can be used to predict long-term or more complex species.

Weeknesses

- The lack of data to a certain extent leads to the possibility of unreasonable parameters
- The guess is too ideal: We mainly use the Gaussian distribution to determine the fungal growth rate and linearly consider the decomposition rate, which resulting in the possibility that our results cannot truly restore the complex natural situation.

Article: The Role of Fungi in the Ecosystem

It is believed that all of you knows fungi that acts as a decomposer in the ecosystem. However, for all the roles that fungi have played in the ecosystem so far, we humans are still constantly exploring.

The decomposition of organic matter is a key component of the carbon cycle. Large-scale modeling of the carbon cycle and global climate models is becoming more refined and incorporating smaller-scale details. An important detail is the rate at which microbial and fungal communities are associated with the decay of organic matter. We have read relevant papers and initially grasped the relevant knowledge about "the influence of various properties of fungi on wood decomposition". To help you better understand the role of fungi, we firstly introduce some basic concepts here.

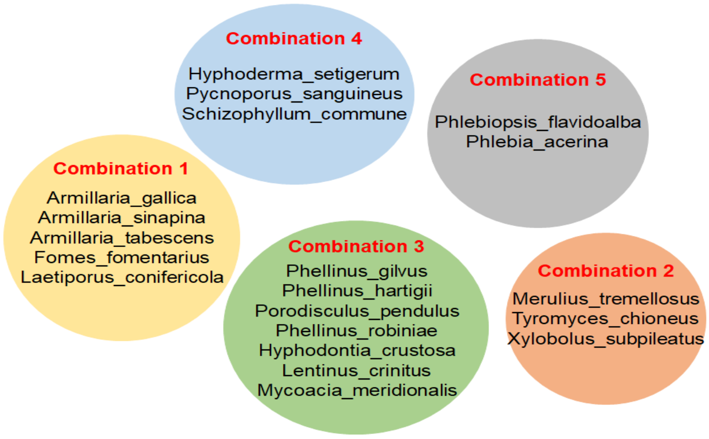
- **Hyphal Extension Rate**: The hyphae are the cells that branch out and form the filaments and structure of a fungus, and the different kind of hyphae play different roles in the life cycle of a fungus. The hyphal extension rate is essentially the growth rate of a fungus. Another trait examined was the density of the hyphae in a given volume.
- **Competitive ranking**: A measure of the ability for a fungus to out-compete other fungi in a series of pair wise tests in similar conditions.
- **Water niche width**: The difference between the maximum and minimum moisture levels in which half of a fungal community can maintain its fastest growth rate.
- **Moisture trade-off**: The difference between a fungus' competitive ranking and its moisture niche width.

Various previous studies have shown that the rate of mycelial extension is related to many characteristics of fungi.For example, it was found that if the hyphal extension rate was larger (faster growth), the fungus was more likely to decompose wood faster. Likewise, if the filaments were denser it was more likely that the decomposition of wood was slower. Additionally, these two traits are also associated with how a fungus reacts to different environmental conditions. Based on it, we studied how fungi react to different environmental conditions. To help you understand our research results better, the following content will introduce our research ideas and methods in detail.

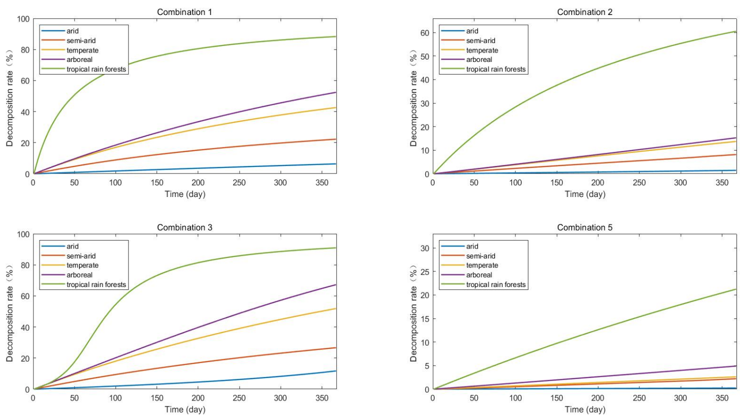
In the study, we selected 20 representative fungi in North America as the research objects. At the same time, we selected five cities that can typically represent five climates: Egypt represents the arid climate, Kenya represents the semi-arid climate, Chicago represents the temperate climate, Australia represents the arboreal environment, and Amazon represents the tropical rain forest. Among all the factors that affect the extension of fungal hyphae and the decomposition of wood, we have found that temperature and moisture have the largest influencing factors. Therefore, we have ignored other influencing factors in our analysis. At the same time, for the effect of fungal decomposition rate, we only considered the five factors which are mycelial extension rate, climate, residual material, fungus moisture resistance, and fungal interaction. In order to calculate the decomposition rate of fungi more accurately, we established a differential equation.

$$\begin{cases} r_i = (1-\frac{y}{y^*})(1-\frac{x}{x^*})r_i^* - \alpha\frac{\sum_{j\neq i} c_j x_j}{\sum_k c_k x_k} \\ d_i = (a_i r_i + b_i e^{m_i} - \beta\frac{\sum_{j\neq i} c_j x_j}{\sum_k c_k x_k})(1-\frac{y}{y^*}) \\ y = \int \sum_i d_i x_i dt \end{cases}$$

By analyzing the competition ranking of fungi, we combine the 20 fungi studied.



Combining the humidity and temperature data of various regions, we have obtained the decomposition rate curves of various combinations of fungi under different climatic conditions.



Actually, we have obtained a lot of images, which you will learn more deeply in the follow-up study. In order to allow you to better understand our current research status, we only cite an example here.

We have obtained that most fungi have the strongest decomposing ability when the ambient temperature is 22°C and the ambient moisture is from 1mpa to 1.5mpa. At the same time, according to the performance of fungi in rapid environmental fluctuations, we also found that the influence of environmental moisture on the decomposition rate of fungi is slightly greater than that of environmental temperature. Most importantly, the more fungi species that exist in the same environment, the better the species diversity, then the stronger the adaptability of the ecosystem in the face of environmental and climate changes, the stronger the decomposing ability of the ecosystem will be. This is the effect of species diversity on the ecology. The importance of the system.

We briefly introduce the results of the research so far here, hoping that you can continue to study for more in-depth knowledge in the university!

References

[1] Nicky Lustenhouwer, Daniel S. Maynard, Mark A. Bradford, Daniel L. Lindner, Brad Oberle, Amy E. Zanne, and Thomas W. Crowther, "A trait-based understanding of wood decomposition by fungi," Proceedings of the National Academy of Sciences of the United States, May 13, 2020.

[2] Daniel S. Maynard,Mark A. Bradford,Kristofer R. Covey,Daniel Lindner,Jessie Glaeser,Douglas A. Talbert,Paul Joshua Tinker,Donald M. Walker,Thomas W. Crowther. Consistent trade-offs in fungal trait expression across broad spatial scales[J]. Nature Microbiology,2019,4(5).

[3]]Daniel S. Maynard,Thomas W. Crowther,Mark A. Bradford. Fungal interactions reduce carbon use efficiency[J]. Ecology Letters,2017,20(8).

Appendices

Appendix A Fungus Name Table

No.	Name
1	Armillaria_gallica_EP102531_C6D
2	Armillaria_gallica_EL8_A6F
3	Armillaria_gallica_FP102534_A5A
4	Armillaria_gallica_FP102535_A5D
5	Armillaria_gallica_FP102542_A5B
6	Armillaria_gallica_HHB12551_C6C
7	Armillaria_gallica_OC1_A6E
8	Armillaria_gallica_SH1_A4A
9	Armillaria_sinapina_PR9
10	Armillaria_tabescens_FP102622_A3C
11	Armillaria_tabescens_TJV93_261_A1E
12	Fomes_fomentarius_TJV93_7_A3E
13	Hyphodontia_crustosa_HHB13392_B7B
14	Hyphoderma_setigerum_HHB12156_B3H
15	Hyphoderma_setigerum_FP150263_B2C
16	Laetiporus_conifericola_HHB15411_C8B
17	Lentinus_crinitus_PR2058_C1B
18	Mycoacia_meridionalis_FP150352_C4E
19	Merulius_tremullosus_FP102301_C3E
20	Merulius_tremellosus_FP150849_C3F
21	Phlebiopsis_flavidoalba_FP102185_B12D
22	Phlebiopsis_flavidoalba_FP150451_A8G
23	Phellinus_gilvus_HHB11977_C4H
24	Phellinus_hartigii_DMR94_44_A10E
25	Porodisculus_pendulus_HHB13576_B12C
26	Phellinus_robiniae_FP135708_A10G
27	Phellinus_robiniae_AZ15_A10H Banik/Mark
28	Phlebia_acerina_MR4280_B9G
29	Phlebia_acerina_DR60_A8A
30	Pycnoporus_sanguineus_PR_SC_95_A11C
31	Schizophyllum_commune_TJV93_5_A10A
32	Schizophyllum_commune_PR1117
33	Tyromyces_chioneus_HHB11933_B10F
34	Xylobolus_subpileatus_FP102567_A11A

Note: The paper of the data source is laboratory data. Take Armillaria_gallica_FP102531_C6D as an example, Armillaria_gallica is the name of the fungus, and FP102531_C6D is the laboratory cultivation plan.