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Team Control Number
1591

Problem Chosen
A

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2021
MCM/ICM
Summary Sheet

An MCM Paper Made by Team 1591

Here is the abstract of your paper.

Firstly, that is ... ofdgdpogopfdofgpsod dfopigposdfgpod dfopgidospigpodgidopifgopdfigopdfigopdigo-pioigopigopfigopdfigopdigpodfigofigpdoopfdigopipodfigopdfigpfgipodifgpodifgpofigopfigodpoigopfigpod Secondly, that is ...

Finally, that is ...

Contents

1 Introduction

1.1 Problem Background

Here is the problem background ...

Two major problems are discussed in this paper, which are:

- Doing the first thing.
- Doing the second thing.

1.2 Literature Review

A literatrue[1] say something about this problem ...

1.3 Our work

We do such things ...

1. We do ...
2. We do ...
3. We do ...

2 Preparation of the Models

2.1 Assumptions

2.2 Notations

The primary notations used in this paper are listed in **Table 1**.

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

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, with fungi being the main factor in the decomposition of wood fibers.

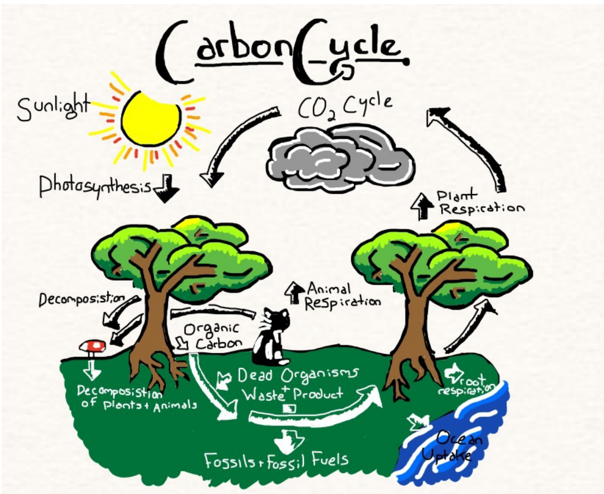

Figure 1: carbon cycle

3.2 Construction of fungal growth rate model

3.2.1 Brief introduction of modeling process

In order to understand how fungi are involved in the decomposition of plant materials and wood fibers, it is necessary to understand the biological characteristics of the fungi involved in the decomposition – the growth rate of the fungi.Consequently, 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 following steps to model the growth rate of the fungus.

1. Step 1: According to the data provided by the data set, the multiple linear regression model between the growth rate and factors that may be related was constructed. Besides, preliminary screening was conducted to obtain the main variables that affect the growth rate according to the significance level of each independent variable.

2. Step 2: The main variables screened out in Step 1 will be verified and interpreted from the biological perspective according to relevant literature. Variables lacking rationality will be excluded. Finally, we will establish the multiple linear regression model of fungi.

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.

3.2.3 Simplified to mathematical model

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

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

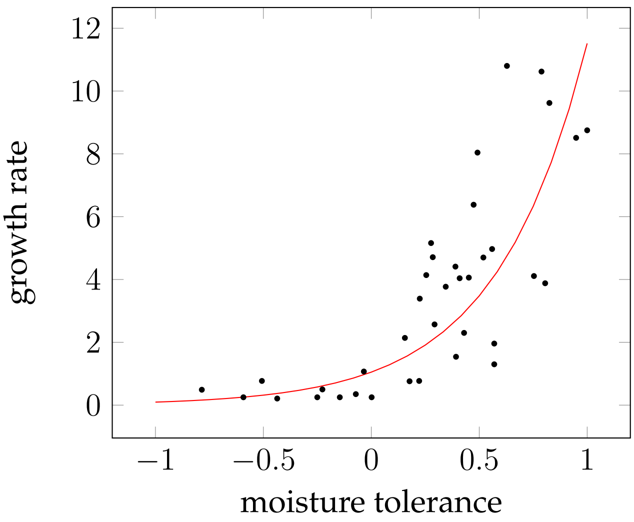

Figure 2: growth rate curve of moisture tolerance

3.3 Construction of decomposition rate model

3.3.1 Brief introduction of modeling process

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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.

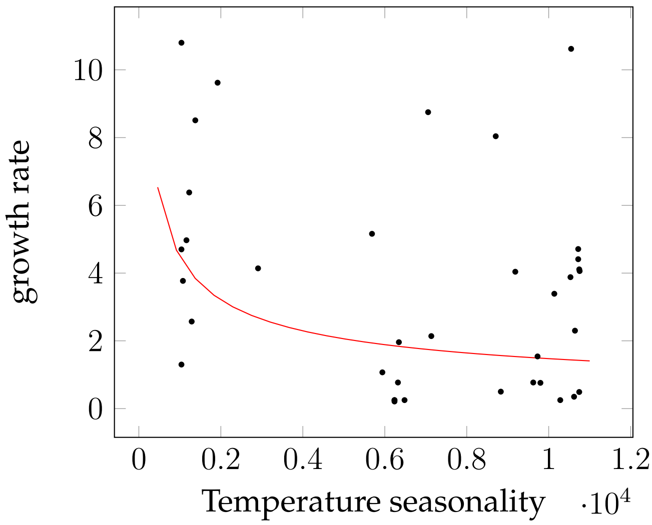

Figure 3: growth rate curve of Temperature seasonality

3.3.3 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

Part I: 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.

The pedigree diagram obtained by the system clustering algorithm.

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.

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.

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 and the literature, we can modify the mycelium density term in the fungal growth rate model and take into account the evolution of the population.

Part three: 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.

The final optimization model can be obtained as follows

5 Strengths and Weaknesses

5.1 Strengths

- First one...
- Second one ...

5.2 Weaknesses

- Only one ...

References

[1] Elisa T. Lee, Oscar T. Survival Analysis in Public Health Research. *Go. College of Public Health*, 1997(18):105-134.

[2] Wikipedia: Proportional hazards model. 2017.11.26. https://en.wikipedia.org/wiki/Proportional_hazards_model

[3] D. S. Maynard et al., Consistent trade-offs in fungal trait expression across broad spatial scales. Nat. Microbiol. 4, 846–853 (2019).

[4] K. L. McGuire, K. K. Treseder, Microbial communities and their relevance for ecosystem models: Decomposition as a case study. Soil Biol. Biochem. 42, 529–535 (2010).

[5]

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Apendix: The source codes

This MATLAB program is used to calculate the value of variable a.

Program 1: `temp.m`

```
a = 0;
for i = 1:5
a = a + 1;
end
```

This LINGO program is used to search the optimize solution of 0-1 problem.

Program 2: `temp.lg4`

```
model:
sets:
WP/1..12/: M, W, X;
endsets
data:
M = 2 5 18 3 2 5 10 4 11 7 14 6;
W = 5 10 13 4 3 11 13 10 8 16 7 4;
enddata
max = @sum(WP:W*X);
@sum(WP: M * X)<=46;
@for(WP: @bin(X));
end
```