Problem Chosen	2021 MCM/ICM Summary Sheet	Team Control Number
A		2124499

Summary

As it is important to know the carbon cycle of the Earth, we should fully understand one key component of the cycle which is the decomposition of plant materials and woody fibers. By learning the process that decompose them, we can use these fungi efficiently. The aim of this report is to build a mathematical and prediction model to evaluate the function and interactive between fungi. We are expected to find the model to measure the influence of different condition in different environment during the decomposition processing. Three main models are established: Model I: Breakdown of the Ground Litter and Woody Fibers Model-with Interactions Between Different Species of Fungi Sub-Model. Model II: Predictions about Relative of Advantages and Disadvantages for Each Species and Combinations of Species Model and Model III: The diversity of fungal communities impact Model.

For Model I: Processing data of decomposition of ground litter and woody fibers was first be collected, and plenty of equations from several papers were introduced in our essay, from relationship between fungi density and woody fibers richness to temperature and moisture influence on fungi. Next, we used the data with the multiple linear regression method to deal with the data. We start from the situation of one kind of fungi, modified the model according to the outcomes and expand it to the case that multiple types of fungi are in presence. Based on the outcome we got, we further analysis the interactions between different species of fungi with multivariate cross analysis and principal component analysis. Besides, we implement the sensitivity analysis as well as robustness analysis.

For Model II: We can use the overall regression model and the individual regression model to simulate the single fungal action and the common fungal action. According to the data we got from the paper, we first build the climate-time model and made the sensitive analysis. Here we used the data for North Hemisphere as an example. As the climate system is nonlinear and sometimes divided into several levels, here we divided the climate system into three levels, X_j for centuries, Y for years, M for months. By using the Thermodynamic formula to get the statistics value, and considered several examples provided in papers, we finally build the model.

For Model III: Based on the data we got from the papers, the combinations of different species were analyzed by data-Decomposition of Forest Litter in Mid-Asia and the combinations of them which were used in the decomposition of garbage already. This model has few equations as the combination of fungi is complex and sometimes hard to analyze. We got some relationship between different fungi with different temperature, environment, combination method, and decomposition materials.

Eventually, we have a conclusion for our report to summarize what we finished and what we still cannot analyze efficiently.

Keywords: Fungi; MATLAB; Computer simulator; Decomposition; Woody fiber

Contents

1 Introduction

1.1 Problem Background

As a decomposer, fungi play a vital role in the carbon cycle of the biosphere. Their decomposing ability is affected by various factors such as moisture tolerance, growth rate, climate, and the interaction between fungi. In order to understand how the above factors change the decomposing of fungi, and predicting the decomposing ability of a specific fungus in a specific environment such as a drought or tropical rain forest. Establish climate dynamics models to predict short-term and long-term trends. On the other hand, fungi play an important role in beneficial waste microbial treatment technology. By understanding the optimal decomposition conditions of different fungi, the waste decomposition process can be made efficient and make greater contributions to environmental protection and economy.

1.2 Restatement of the Problem

- Build a mathematical model to estimate the decomposition rate of plant material and woody fibers when multiple kinds of fungi are existed.
- Optimize the model to take into account the interaction between different types of fungi of different traits.
- Analyse the results of the model in terms of long-term and short-term trends of fungal interactions. Point out the effects of weather pattern changes on their interactions.
- Point out the advantages and disadvantages of different species combinations under different temperature and humidity.
- Study how the efficiency of fungal decomposition affects the efficiency of waste classification system.

1.3 Our Approach

We start from the situation of one kind of fungi, using the method of multiple linear regression to deal with the decomposition rate data of 27 kinds of fungi in different temperature and humidity through MATLAB, modified the model according to the results and expand it to the case that multiple types of fungi are in presence. Based on the outcome we got, we further analysis the interactions between different species of fungi with multivariate cross analysis and principal component analysis. Besides, we implement the sensitivity analysis as well as robustness analysis. Then, we build the climate-time model and made the sensitive analysis to atmosphere and climate change.

2 General Assumptions and Model Overview

To simplify our problems, we make the following basic assumptions:

- The main traits we consider in the model are just the growth rate of the fungus and the fungus' tolerance to moisture.
- It is assumed that fungi will not produce mutually exclusive substances and reactions in different stages of garbage disposal.
- It is demonstrated that although the composition of the treated organic matter is uncertain, organic waste is generally harmless to organisms.

3 Analysis and Modeling

3.1 Decomposition model of multiple Fungi based on multiple linear regression analysis

According to biological research and analysis, temperature, humidity, acidity and alkalinity, mycelial elongation rate, and fungus' tolerance to moisture all affect the decomposition of plant materials and woody fibers. Here we only focus on two primary and interrelated factors: the growth rate of the fungus and their tolerance to moisture. To build a model that describes the relationship between growth rate and humidity tolerance of fungi, we simplify the over complex formula into some simple influence factors, that is:

Independent variables:

- Growth rate of the fungus (denoted by x_1).
- The tolerance to moisture of the fungus (denoted by x_2).

Dependent variables:

- Decomposition rate of the woody fibers (denoted by y). It can be calculated from the variance of our data "Decomposition rate of 27 kinds of fungi toward cellulose in 10,16,22 Celsius degree", because it describes the change of decomposition rate affected by variation of temperature and humidity.

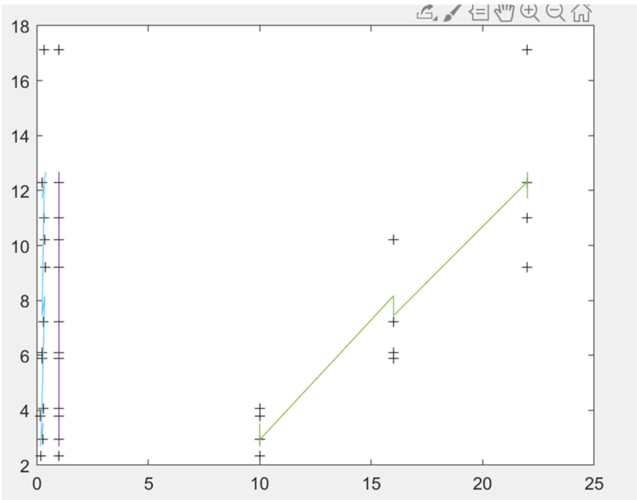
In this way, we can set up multiple linear regression model. We start from the simple case that only one type of fungi in existence (β is the coefficient of multiple linear regression equation):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

According to the least square criterion, the model coefficients can be obtained by data fitting method in MATLAB using our data of 27 kinds of fungi decompose cellulose. Although this can roughly describe the trend of data points, but the fitting is not good, we still need to improve the effectiveness and accuracy of the model. We rewrite the model as:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \epsilon$$

Random error ϵ is the sum of influence on y apart from two independent variables. We suppose it is independent random variable for different x, subject to distribution N(0,σ^2). The difference between the actual value of y and the predicted value is the residual of the model, which is regarded as the estimated value of random error and should obey the normal distribution with the mean value of 0. If it is found that the confidence interval of the residuals of some data does not contain zero, it can be considered as outliers, they deviate from the trend of the overall data, and should be eliminated. After modification, the confidence interval and variance of the coefficients both decrease, which means the accuracy of the model is improved.



For a more accurate influence factor ϵ, we have to consider a variety of factors discussed in the given paper. The number and growth rate of fungi are not mentioned in the research result, but we think it must be negatively correlated. According to the S curve in biology, we assume that its influence factor is 0.4.

There was a positive correlation between the elongation rate and the decomposition rate of fungi, which increased rapidly at low temperature and tended to be stable at high temperature, and finally converged to a slope of 0.39 $\pm$ 0.09 in log-log.

The effect of temperature on the decomposition rate is positively correlated, but it should not be too high (the specific value is not given there). We can suppose that the influence factor of temperature rise is between 0.3-0.4 according to the image. It can be divided into three levels: 1.3 1.6 1.9.

Fungi with high environmental adaptability (tolerant to various water conditions) have low decomposition rate, it can reach k = 0.82 + 0.28 as a line. According to the moisture resistance of the paper, it can be divided into three grades: 0.82,0.91,1.0. Since there are two kinds of catabolizing enzymes, the external enzyme plays a major role in the decomposition, and the acid environment has the greatest effect on the decomposition of fungi, which can reach k = - 0.3 in log-log. We assume that the pH value is 0 at this time, and the pH value of strong alkali is 10.

Thus, we obtain:

$$\epsilon = (-0.3 + 0.13 * PH) * (1 + 0.3 * T)$$

We expand the model to the situation of a variety types of fungi in presence. For multiple kinds of fungi, their n groups of observed values are x_{m1}, y_m (m=1,2,3,...,n):

$$\begin{cases} y_1 = \beta_{01} + \beta_{11}x_{11} + \beta_{12}x_{12} + \epsilon_1 \\ y_2 = \beta_{02} + \beta_{21}x_{21} + \beta_{22}x_{22} + \epsilon_2 \\ y_3 = \beta_{03} + \beta_{31}x_{31} + \beta_{32}x_{32} + \epsilon_3 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ y_n = \beta_{0n} + \beta_{n1}x_{n1} + \beta_{n2}x_{n2} + \epsilon_n \end{cases}$$

For the model of multiple kinds of fungi in existence, we need to describe the combined action of different fungal species. Our approach is ,the factors influencing the decomposition rate of each fungus, that is, those two original independent variables, were extracted as coefficients of decomposition ability of different fungi, and the number of different fungi in a given area was taken as independent variables, that is:

$$y = \gamma_1 a_1 + \gamma_2 a_2 + ... + \gamma_n a_n$$

Also, we noticed that there is a relationship between those two traits, the slow growing strains of fungi tend to be better able to survive and grow in the presence of environmental changes with respect to moisture and temperature, while the faster growing strains tend to be less robust to the same changes. Thus, we have:

$$x_{n1} = \alpha x_{n2}$$

It can be used to the models through back substitution.

3.2 Decomposition model of interaction among different Fungi based on principal component analysis

We regard the characteristics of 27 fungi as a 27 dimensional random variable, assume that their expectation vector and covariance matrix are known, and construct 27 linear combinations with a set of unit vectors:

$$\begin{cases} y_1 = \gamma_{11}b_1 + \gamma_{12}b_2 + ... + \gamma_{1n}b_n = a_1^T x \\ y_2 = \gamma_{21}b_1 + \gamma_{22}b_2 + ... + \gamma_{2n}b_n = a_2^T x \\ y_3 = \gamma_{31}b_1 + \gamma_{32}b_2 + ... + \gamma_{3n}b_n = a_3^T x \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ y_n = \gamma_{n1}b_1 + \gamma_{n2}b_2 + ... + \gamma_{nn}b_n = a_n^T x \end{cases}$$

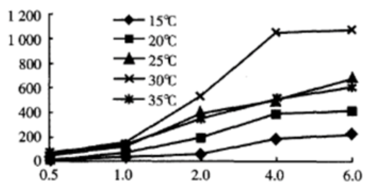
$$y = Ax, A = (a_1, a_2, ..., a_3)^T$$

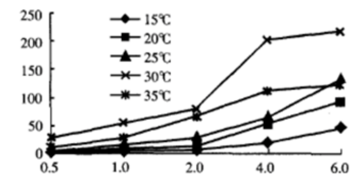
Since the covariance matrix of Y is diagonal, we are able to determine principal component coefficient by:

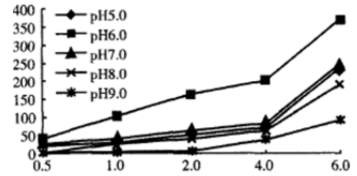
$$Cov(y) = Cov(Ax) = ACov(x)A^T = diag(\lambda_1, \lambda_2, ..., \lambda_n)$$

There must be a set of unit orthogonal eigenvectors to form an orthogonal matrix since the covariance matrix is a symmetric positive definite matrix. The function command for principal component analysis in MATLAB is princip: [COEFF, SCORE, LATENT] = princomp(X) The input parameter x is the observation data matrix, each row corresponds to an observation value, each column corresponds to a variable, and the output parameter x is the input parameter CCOEFF is the coefficient matrix of principal component, and the j-th column is the coefficient vector of the j-th principal component; SCORE is the score matrix, and the i-th row and j-th column elements are the scores of the i-th observation value and the j-th principal component; LATENT is the vector formed by sorting the eigenvalues of X according to the value. We need to pay attention that the princomp function centralizes the observed data, that is, each element of X subtracts the mean value of its column. Accordingly, its output is also the centralized principal component coefficient.

We also have a research on the interaction between white rot fungi and brown rot fungi.





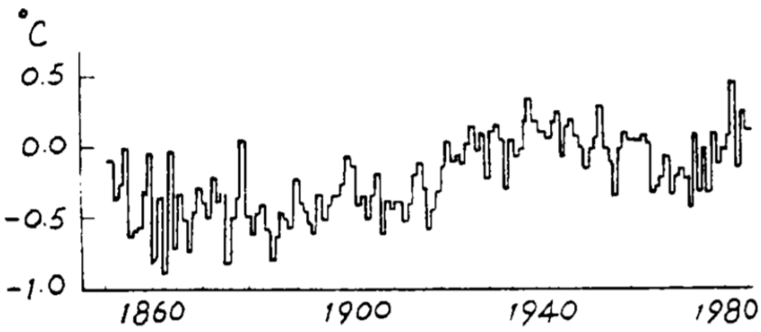


First of all, for the white rot fungi with the strongest decomposition ability, the requirements for nutrients are not high. Using cheap nutrients such as wood chips and sawdust can effectively cultivate them, while other fungi often can not use simple cheap nutrients, which makes it easier for white rot fungi to establish their survival status in the competition of real fungi. Secondly, in the process of decomposition, the white rot fungus will produce - Oh oxygen free radicals, oxidize the protein and DNA of other microorganisms, making other microorganisms unable to survive. Moreover, white rot fungi can use redox system on their plasma membrane to regulate the pH value of their environment, resulting in the decline of microbial activity which is not at the same optimal pH value.

It can be seen from the paper that the most suitable growth environment of brown rot fungus and white rot fungus is basically the same, we can think that it is a competitive relationship, and because the decomposition rate of cellulose of white rot fungus is higher than that of brown rot fungus, brown rot fungus is in the downwind in the competition for white rot fungus. That is to say, the s-survival curve of white rot fungi will reach the peak earlier than that of brown rot fungi, and white rot fungi will be in the leading position in the subsequent competitive fluctuation relationship, but white rot fungi will not eliminate brown rot fungi due to environmental constraints, and finally both of them reach a stable state, and the number of brown rot fungi should be lower than that of white rot fungi.

3.3 Interaction analysis based on climate time series model

To solve this problem, we build a climate time series model and make sensitivity analysis. Taking the change of surface temperature in the northern hemisphere as an example. The climate system is a non-linear system, in which there are many different



time and space scales, forming a multi-level structure. Different levels present a high degree of self-organization, and the most obvious performance is the mutual transformation of climate state. Therefore, the high level of climate is the concentrated performance of the low level, and the high level reflects the main characteristics of the low level The low level can be regarded as high-level damping or fluctuation, thus forming a diversified climate state. For a stable climate system, suppose that the set T_i is used to represent the time series of temperature, and X_j is used to represent the average of a certain common subsequence of T, then the climate level represented by series X_a, X_i,...,X_m is higher than that described by T_i, because each x value represents the statistical behavior of a certain sub segment. Therefore, we establish three levels of D-C, Y and M, which are respectively represented by X_j series (time scale of decades or even centuries), T_i series (time scale of years) and monthly time series.

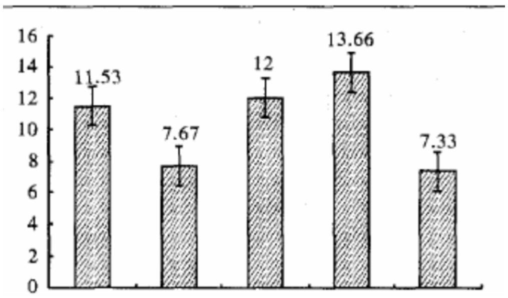
The thermodynamic formula $S = kln\Omega$ clarifies that the high level is represented by the low level, that is, the statistical average value of $X_j = T_j$. 1920 is the first mutation point, so we assume that the value is -0.22614 (average value of 1851-1920), -0.052 (average value of 1921-1984) is the second point. Starting from D-C layer, the function u(T) describing the subsequent behavior of Y layer is as follows:

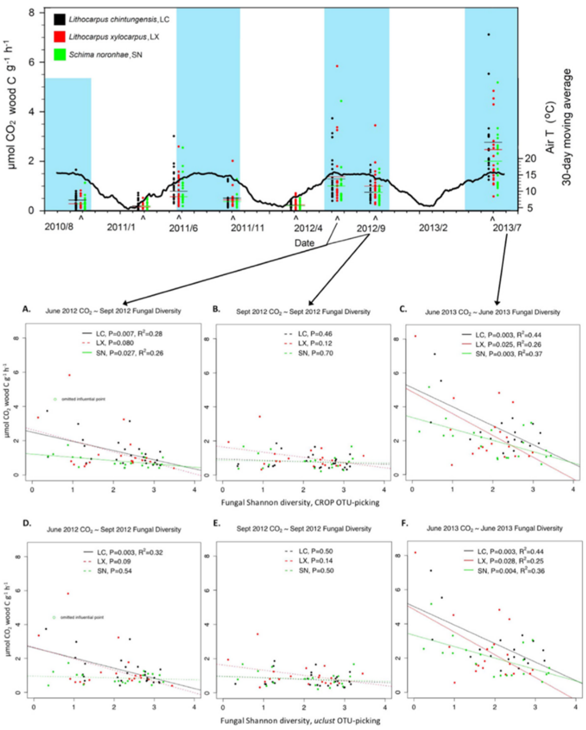
$$u(T) = aT^4 + bT^3 + cT^2 + dT + e$$

So we can write out the equation to describe the temperature change in the northern hemisphere:

$$\frac{dT}{d\tau} = -T^3 + \lambda_1 T^2 - \lambda_2 T + \lambda_3 = f(T, \lambda_i)$$

For the change of temperature and humidity, according to the paper "the influence of climate drying and warming on the composition and diversity of culturable fungi in desert steppe soil of Inner Mongolia", according to the experimental data in the figure below, climate warming and drying are not conducive to the survival of dominant fungi in soil, but may also promote the emergence of a small number of stress resistant bacteria.





Finally, in September 2012, CO_2 emissions did not decrease with the increase of fungal diversity, which is consistent with the generally low CO_2 emissions in September. The first is the "pure diversity" effect, that is, species characteristics are not important, but the increase of species richness and evenness itself is the reason for the slow down of wood decomposition to some extent. The second is the "species selection" effect, in which the more diverse fungal communities are more likely to contain specific species that cause slow decomposition and control the overall decomposition rate of wood blocks in some way. Through discussion we found that naturally settled wood with more different fungal communities decomposes more slowly, resulting in a negative correlation between fungal biodiversity and ecosystem functions of decomposition. The results showed that there was a positive correlation between fungal diversity and carbon storage in forest and ecosystem services providing wood decomposition habitat Fungal diversity and CO_2 emission rate were measured simultaneously. We observed that the relationship between CO_2 emission rate and fungal diversity varies from month to month and from tree species, indicating that fungal activity and composition are dynamic and environmentally responsive.

3.4 Prediction of fungal decomposition under different climatic conditions

For tropical rain forest, according to the paper "dynamics of microorganism and enzyme activity in litter decomposition process of Pinus massoniana forest in middle subtropical zone", the research of criquet et al and Zhang Ruiqing et al. In tropical zone shows that microorganism becomes the main decomposer by producing and optimizing the distribution of enzymes related to C, N and P cycle However, Waring's research in tropical areas showed that the differences in litter composition significantly affected the overall level of fungal richness and enzyme activity.

45	0.617 ±0.197 dB	0.203 ±0.096 fB	0.137 ±0.030 cB	0.957 ±0.323 dC
90	0.732 ±0.211 dA	37.679 ±8.026 bA	0.081 ±0.028 cA	38.492 ±8.275 bA
135	0.068 ±0.026 eA	155.111 ±31.274 aA	0.010 ±0.004 dB	155.189 ±31.304 aA
180	0.579 ±0.163 dA	11.333 ±1.006 cA	0.500 ±0.087 aA	12.412 ±1.256 cA
225	6.219 ±1.802 abB	7.442 ±1.178 dA	0.311 ±0.054 bA	13.972 ±3.034 cB
270	4.698 ±1.224 bA	11.711 ±1.110 cA	0.099 ±0.032 cA	16.508 ±2.366 cA
315	8.678 ±2.513 aA	2.197 ±0.985 eA	0.453 ±0.066 aA	11.328 ±3.564 cA
360	2.110 ±0.756 cA	12.171 ±1.014 cA	0.315 ±0.058 bA	14.596 ±1.828 cA
45	23.176 ±5.134 aA	7.738 ±0.973 bA	0.091 ±0.021 aB	31.005 ±6.128 bA
90	0.136 ±0.098 cB	7.178 ±1.012bC	0.063 ±0.009 aA	7.377 ±1.119 cC
135	0.079 ±0.021 cA	100.284 ±26.301 aA	0.008 ±0.004 cB	100.370 ±26.326 aA
180	0.229 ±0.161 cB	0.139 ±0.052 dC	0.072 ±0.010 aC	0.440 ±0.223 dC
225	0.582 ±0.301 bcC	0.230 ±0.097 dB	0.061 ±0.010 aB	0.873 ±0.408 dC
270	0.271 ±0.125 cB	0.824 ±0.207 cB	0.016 ±0.006 bcB	1.111 ±0.338 dC
315	1.025 ±0.473 bC	0.100 ±0.049 dC	0.028 ±0.008 bC	1.153 ±0.530 dC
360	0.094 ±0.066 cB	0.008 ±0.002 eC	0.024 ±0.006 bC	0.126 ±0.074 eC
45	0.704 ±0.203 cB	9.614 ±1.529 bcA	0.330 ±0.097 aA	10.648 ±1.829 bB
90	0.180 ±0.092 dB	14.058 ±3.015 bB	0.096 ±0.023 bA	14.334 ±3.130 bB
135	0.101 ±0.047 dA	29.467 ±6.334 aB	0.022 ±0.007 dA	29.590 ±6.388 aB
180	0.522 ±0.100 cA	0.775 ±0.225 eB	0.126 ±0.023 bB	1.423 ±0.348 dB
225	14.818 ±2.315 aA	7.175 ±2.236 cA	0.056 ±0.011 cB	22.049 ±4.562 aA
270	2.367 ±1.118 bA	0.641 ±0.212 eB	0.022 ±0.009 dB	3.030 ±1.339 dB
315	3.093 ±1.032 bB	0.398 ±0.168 eB	0.059 ±0.012 cB	3.550 ±1.212 cdB
360	3.003 ±0.998 bA	3.502 ±1.020 dB	0.093 ±0.022 bB	6.598 ±2.040 cB

3.5 Effect of fungi and microorganisms on garbage classification

According to the "Study on microbial characteristics of municipal solid waste composting", temperature is the key factor in the process of microbial treatment of municipal solid waste. In the initial stage of composting, microorganisms propagate in large numbers and metabolize to produce a lot of heat. When the temperature is 40-50 Celsius degree, mesophilic bacteria are in the best condition. When the temperature continues to rise, mesophilic bacteria are inhibited and thermophilic bacteria enter the excited state. However, when the temperature exceeds the optimal temperature, mesophilic bacteria are in the best condition According to the experimental results, 55 Celsius degree is the best physiological temperature for composting. According to the research "Composting Process of Municipal Solid Waste with High Effective Complex Microbial Community Xi Beidou1, Liu Hongliang2, Meng Wei2, Li Handong2, Wang Qingsheng2", Through the high-efficiency compound microbial flora for the mixed composting of domestic waste and sludge, that is to improve the biodiversity of fungal colony, can improve the biodegradation rate of organic pollutants. The microbial colony is composed of yeast, actinomycetes, lactic acid bacteria, nitrogen fixing bacteria, cellulose decomposing bacteria and other microorganisms. In the initial stage of MSW microbial treatment, microorganisms decompose organic matter and make the temperature rise to about 40 Celsius degree. The normal temperature bacteria are inhibited and the total number of bacteria decreases. At this time, the thermophilic bacteria slowly grow and reproduce, and the genus of bacteria increases. When the temperature reaches 55-60 Celsius degree, the thermophilic bacteria are inhibited, and the thermophilic bacteria begin to be active. When the temperature is higher than 60 Celsius degree, some thermophilic bacteria die or dormant, which can be used to treat MSW It can be seen that a complex and stable ecological balance system is formed by highly efficient complex microbial flora (high fungal community diversity). In the microbial treatment of organic waste, the total number of bacteria can remain relatively stable.

4 Sensitivity Analysis and Robustness Analysis

F-test:

$$f = \frac{R^2/k}{(1-R^2)/[n-(k+1)]}$$

Goodness of fit test:

$$R^2 = \frac{SSR}{SST}rac$$

T-test:

$$t = \frac{\beta/\sqrt{C}}{\sqrt{SSE/(N-K-1)}}$$

5 Strengths and Weakness

Our model basically explains, analyzes and forecasts the given problems, but due to the lack of relevant data, the fitting accuracy needs to be improved. In addition, we are not clear about the mechanism of action between strains, and there are some deviations in the prediction of climate change and garbage classification.

6 References

- Li Huirong. "Research progress of white rot fungi." progress in Environmental Science 6 (1996): 69-77

- Wu Jinping, Jiao zhenbiao, Chen Leifu, Jiao ZHONGJIU, Qiu Zhengming. (2014). Study on the factors influencing the identification of soft rot fungi infecting konjac roots. Hubei Agricultural Sciences, 128-131. Doi: Hubei Agricultural Sciences

- https://www.ixueshu.com/document/319e6999157ccb8f318947a18e7f9386.html

- Higher fungal diversity is correlated with lower CO2 emissions from dead wood in a natural forest Chunyan Yang1,*, Douglas A. Schaefer2,*, Weijie Liu2, Viorel D. Popescu3,4, Chenxue Yang1, Xiaoyang Wang1, Chunying Wu1 Douglas W. Yu1,5

- https://www.nature.com/articles/srep31066.pdf

- “Composting Process of Municipal Solid Waste with High Effective Complex Microbial Community Xi Beidou1, Liu Hongliang2, Meng Wei2, Li Handong2, Wang

Qingsheng2(1. Department of Environmental Engineering, Tsinghua University, Beijing 100084, China E-mail: xibeidou@263. net; 2. Chinese Research Academy of Environmental Science, Beijing 100084, China)"

- 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

7 Appendix

7.1 short essay

As a decomposer, fungi play a vital role in the carbon cycle of the biosphere. Their decomposing ability is affected by various factors such as moisture tolerance, growth rate, climate, and interaction between fungi. On the other hand, fungal strains that grow slowly In the presence of environmental changes, they tend to survive and grow better, while strains that grow faster are often less stable to the same changes.

Research on climate change can predict long-term and short-term trends, and further predict the impact on fungal colonies. The climate system is a non-linear system that contains many different time scales and space scales, forming a multi-level structure, and different climate states can be converted to each other, and the climate levels are also high and low. For example, The Sahara Desert is generally an arid area, a typical tropical desert climate. However, there may be a certain amount of rainfall in the Sahara Desert on a certain day, but the rainfall on that day must be much lower than that of the tropical rain forest climate, so the climate is high. It is the concentrated performance of the low level, the high level embodies the main characteristics of the low level, and the low level can be regarded as the high level of damping or fluctuation, thus forming a diversified climate state.

Biological treatment of domestic waste is a treatment technology that uses organisms in nature, mainly microorganisms, to convert the degradable organic matter in domestic waste into stable products, energy and other useful substances, so as to reduce the amount of domestic waste and be harmless And resource. The main biological treatment technologies include aerobic technology and anaerobic technology. The aerobic technology is represented by composting to obtain organic fertilizer. The anaerobic technology is mainly based on anaerobic digestion to obtain high-value products such as biogas, which can be used to generate electricity or replace natural gas and fuel oil.

In the process of microbial treatment of organic waste, fungi play an important role, so how to maximize the activity of fungi and then decompose waste to the greatest extent is a problem we need to solve at present. According to the research institute, the main factor that affects fungal activity is temperature. At the same time, different bacteria have different ability to withstand temperature, and the best activity temperature range is also different, and their effects are also different. Therefore, in the process of microbial treatment of organic waste, Combinations of different types of bacteria are used. In the early stage of garbage microbial treatment, the microorganisms decompose the organic matter so that the temperature rises to about 40 degrees. Normal temperature bacteria are inhibited, and the total bacterial count decreases. At this time, the mesophilic bacteria slowly grow and multiply, and the bacteria in the genus grow. When the temperature reaches 55-60 degrees, the mesophilic bacteria are inhibited, and the thermophilic bacteria become active. When the temperature is greater than 60 degrees, the thermophilic bacteria partially die or dormant. It can be seen that the high-efficiency composite microbial flora (high fungal community diversity)) Has formed a complex and stable ecological balance system. In the microbial treatment of organic waste, the total number of bacteria can remain relatively stable.

Although the fungus is small, it plays a vital role in our lives. Only a better understanding of it can make it serve our lives better.

7.2 code

```
clear;clc;
xtemperature = [ 10 10 10 10 16 16 16 16 22 22 22 22];
xDecomposition = [4.07 2.94 3.78 2.35 10.21 6.09 7.23 5.9 17.12 11 12.3 9.2 ];
xExtension = [ 0.3 0.26 0.16 0.2 0.36 0.24 0.3 0.24 0.34 0.32 0.24 0.4 ];
y = xDecomposition;
X = [ones(length(y), 1),xtemperature',xExtension']
Y = y'
[b,bint,r,rint,stats] = regress(Y,X);
b,bint,stats
figure(1);
rcoplot(r,rint)
figure(2);
z=b(1)+b(2)*xtemperature+b(3)*xExtension;
plot(X,y,'k+',X,z)
```