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Study on the Relationship between the Interaction of Different Fungi and Environment Change

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Abstract: *Fungi, as decomposers, mainly decompose wood fibers and litter. The decomposition of wood fiber and litter is an important part of the ecosystem cycle. The aim of this study is to establish a fungal population competition model to simulate the effects of the intrinsic characteristics of fungi on the interactions between different fungi. In addition, the effects of short - and long-term climatic changes on fungal community interactions, as well as the advantages and disadvantages of fungi in communities under different climatic conditions are studied. This study hopes to find and predict the rules between the fungal decomposition process and the ecological environment, and explore the effects of fungal species diversity on the ecosystem. First use ARIMA (0,1,0) to predict the trend of temperature change in Europe in the next three years, and then use Power BI to predict the trend of precipitation change in Europe in the next three years. Next using Linear interpolation method for curve fitting, fitting out the temperature - humidity - fungal distribution density diagram, and then for a long-term in Europe (2009-2023 - the temperature of precipitation data) and short-term rainfall anomaly in London (2018-2019 years) in the diagram, respectively for long-term and short-term trend of fungal distribution density changing with time.*

Keywords: *Fungus, ARIMA, decomposers, Environment*

1. Introduction

The carbon cycle describes the process of carbon exchange in the earth's biological cycle and is an important part of life on earth. The process of the carbon cycle involves the decomposition of compounds so that carbon can be renewed and used in other forms. A key component of this process is the decomposition of ground litter and wood fibers.

Fungi are the main factors in the decomposition of wood fiber. And the rate of decomposition of fungi is related to some of its characteristics. For example, slow-growing strains tend to be better able to survive and grow through environmental changes such as humidity and temperature, while faster-growing strains tend to be less robust to the same changes.

A number of researchers have previously contributed to data analysis models for fungi. The study of O. J. B. L. Hiscox J illustrates the results of interspecific competition among fungi [2]. M. A. Daniel S.Maynard conducted several experiments on fungi, indicated that there was a certain relationship between various characteristics, and provided detailed values of fungal characteristics and experimental data [1]. P. K. Tomas Vetrovsky's research provided dataset which can be used to fit the relationship between temperature, humidity and the distribution density of fungi [3]. M. Loreau shows how nutrients move through an ecosystem and builds models to measure the efficiency of recycling [4].

The project requires the establishment of a model of fungal growth rate, moisture tolerance and interaction on the decomposition of ground litter and woody fibers.

- Define the overall efficiency of the system related to decomposition efficiency, and calculate the overall efficiency of each colony and the combination of colonies most likely to persist.
- Discuss the importance and role of biodiversity for different levels of local environmental change.

2. Data

2.1 Data Source

The data this paper used mainly include historical weather data, the area where the fungus is found

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and data on experiments involving growing fungi. The data sources are summarized in Table 1.

Table 1: Data source collation

Database Name	Database Websites	Data Type
World Weather Online	https://www.worldweatheronline.com/	Geography
GBIF	https://www.gbif.org/	Biology
Nature	https://www.nature.com/	Academic paper

2.2 Data Cleaning

For simulating interspecific competition of multiple fungi, the input data of the model should be cleaned. The original dataset had 615 sets of data. After eliminating invalid data from the original data set (the competitive ranking was 0 after normalization, the lack of sufficient information on fungi or the absence of experimental results), 540 sets of valid data were obtained.

In the second model, linear spline interpolation is required for temperature, humidity, and density to determine the density of the fungal community. However, the range obtained after interpolation is not complete enough to cover all the temperature and humidity ranges. If humidity and temperature are entered outside the range, the result is NaN. Since NaN has no data, use 0 instead.

3. Interactions of Fungi under External Changes

Short-term and long-term environmental trends can affect the interaction of different species of fungi. Short-term rapid fluctuations in the environment may be caused by natural disasters or some unusual climate change, while long-term trends in the atmosphere may be global warming or seasonal climate change.

3.1 Long-Term Trends

For the study of long-term atmospheric trends affecting the interaction of different species of fungi, this method first predicts the average monthly temperature for the next 3 years based on the average monthly temperature data for Europe from 2009 to 2020. For the prediction of future temperature, this method uses time series analysis with the help of software SPSS. Time series analysis can be divided into three parts: describing the past, analyzing the law, and predicting the future. Since the average monthly temperature in Europe is a periodic data, this method tries the simple seasonal model, Winteraddition and Wintermultiplication models, ARMA model and ARIMA model, and finally finds that ARIMA (p,1,q) model has the highest degree of fit and is the best prediction model. The following figure shows the parameters of ARIMA model fitting degree generated by SPSS software:

Model Fit

					Percentile						
Fit Statistic	Mean	SE	Minimum	Maximum	5	10	25	50	75	90	95
Stationary R-squared	.390	.	.390	.390	.390	.390	.390	.390	.390	.390	.390
R-squared	.899	.	.899	.899	.899	.899	.899	.899	.899	.899	.899
RMSE	1.761	.	1.761	1.761	1.761	1.761	1.761	1.761	1.761	1.761	1.761
MAPE	16.424	.	16.424	16.424	16.424	16.424	16.424	16.424	16.424	16.424	16.424
MaxAPE	200.000	.	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000
MAE	1.429	.	1.429	1.429	1.429	1.429	1.429	1.429	1.429	1.429	1.429
MaxAE	4.339	.	4.339	4.339	4.339	4.339	4.339	4.339	4.339	4.339	4.339
Normalized BIC	1.352	.	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352

Figure 1: ARIMA model fitting degree parameter table

The mathematical representations of the principle of ARIMA (p,1,q) model are as follows:

$$Y_t^{'} = \beta_0 + \sum_{i=1}^{p} \beta_i \times Y_{t-i}^{'} + \eta_i + \sum_{i=1}^{q} \lambda_i \times \eta_{t-i} \quad (1)$$

$$Y_t^{'} = (1-\tau) \times Y_t \quad (2)$$

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$$(1-\sum_{i=1}^{p}\beta_i \times \tau^i)\times(1-\tau)\times Y_t = \beta_0 + (1+\sum_{i=1}^{q}\lambda_i \times \tau^i)\times \eta_t \quad (3)$$

Finally, the average monthly temperature in the next three years predicted by this model is shown in the figure below:

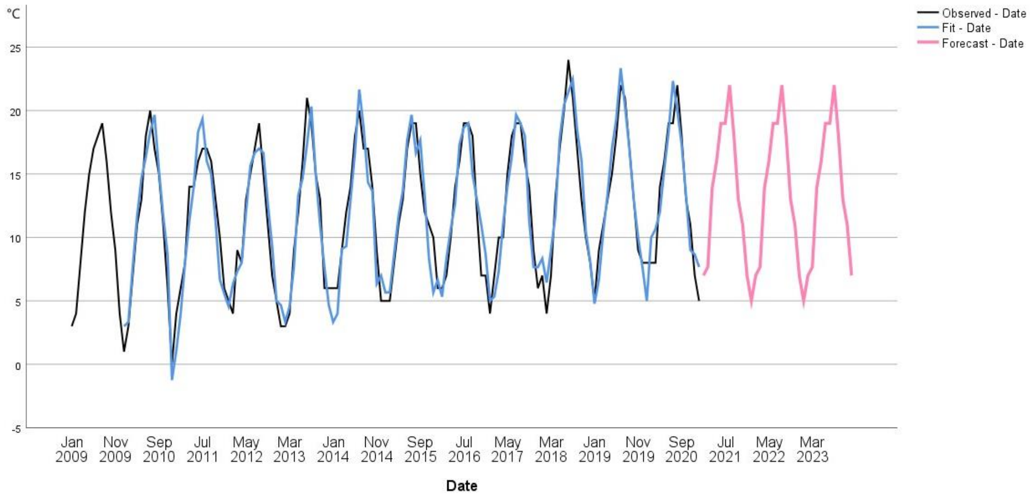

Figure 2: European temperature forecast results

Precipitation prediction in Europe was realized with the help of the software Power BI, and the results are shown below:

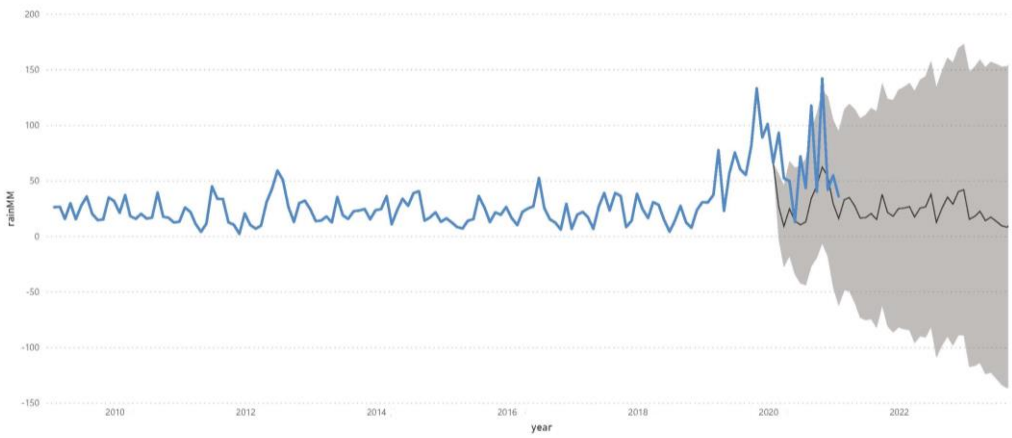

Figure 3: Precipitation forecasts for Europe

Next, several sets of temperature-humidity-fungus distribution density data are selected by using the data set in Reference [3] and Linear interpolation method is used for curve fitting. This is a method of curve fitting using linear polynomials. Finally, the relationship between the distribution density of fungi and temperature and humidity was fitted. The mathematical representations of the Linear interpolation method are as follows:

$$E_T = f(x) - M(x) \quad (4)$$

$$M(x) = f(x_0) + \frac{f(x_1) - f(x_0)}{x_1 - x_0}\times(x - x_0) \quad (5)$$

$$|E_T| \le \frac{(x_1 - x_0)^2}{8}\max_{x_0 \le x \le x_1}|f''(x)| (Rolle's\ theorem) \quad (6)$$

Where E_T is approximate error and M is linear interpolation polynomial.

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Finally, the previously predicted European temperature and humidity data are substituted into the "temperature-humidity-fungus distribution density" relationship, and the trend chart of fungal distribution density in Europe from 2009 to 2023 is obtained. Because of the previous assumption that the fungal distribution density can be equivalent to the fungal size ratio, the fungal distribution density can also represent the interaction between fungal communities.

3.2 Short-Term Trends

For the study of short-term climate abrupt change affecting the interaction of different species of fungi, this report chooses to study the abnormal rainfall in London from 2018 to 2019 as shown in Figure 4. Firstly, the temperature and precipitation data before and after the occurrence of "abnormal rainfall" were selected, and then substituted into the "temperature-humidity-fungus distribution density" relation graph to get the change trend of fungus distribution density before and after the occurrence of "abnormal rainfall".

4. Conclusion

As can be seen from the figure, the density of the colony changes periodically over time, but the overall trend is that the density of the colony decreases gradually. Therefore, long-term climate dynamics, namely global warming, may lead to a gradual decrease in the density of colonies and a decrease in the diversity of fungal species.

As for the study on the impact of short-term abrupt climate change on the interaction of different species of fungi, it can be seen from Figure 6 that the fungal density was abnormally low due to abnormal precipitation in the following years. Therefore, short-term climate changes may also have a large impact on fungal interactions.

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