Analysis of fungal system decomposition ability under Ka-Volterra model

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Abstract: Differential equations are used to describe the decomposition ability of fungi and systems with multiple species under the influence of various factors. These factors include characteristics of the fungus itself, such as mycelium elongation, water tolerance, interactions between fungal populations, and the effects of the external environment. With reference to the classical population model and the Karvolterra differential equation model, the research made a further extension on these two models to describe the change of the population size along with the time and the decomposition ability of different species of fungi by adding a series of influencing factors to the equation. The effect of the interaction between various fungi on the decomposition rate was considered. Finally, we describe the trend of the overall decomposing ability of the system under the external environment. In summary, our model starts from initial models that describe populations of different species and the wood decomposition capacity of fungi under the influence of various factors, and simulates the wood decomposition capacity of a realistic polyfungal system on a given land.

Keywords: Differencial Equations; Lotka-Volterra Model; Dynamic Behavior; Biodiver- sity; Clustering; Linear Regression

Introduction

The process of carbon exchange in the geochemical cycle is called the carbon cycle, and the decomposition of compounds is an indispensable part of it[1]. In such a process, a vital component is the decomposition of plant material and wood fibers. According to some researches, it is found that the key species that decomposes them is fungi. Under different influencing factors and traits, the decomposing ability of fungi is also different. In addition, the external temperature and moisture and its hyphal extension rate also play important roles in the decomposition ability of specific fungi[2]. At the same time, combined with the competition among the fungal populations, it can be found that the advantages and disadvantages of the combination of different systems are related to the actual external environment. The diversity of fungal species also promotes the decomposition ability of ground garbage to a certain extent, which has a wide range of practical applications and plays very important roles[3].

1 Problem analysis

It is necessary to describe the rate of change in the decomposition ability of breakdown of ground litter and woody fibers, and consider the influencing factors. Combined with the method of differential equations and Lotka-Volterra model, we can list the equation of the decomposition ability of each fungus over time, and express it in the form of a matrix[4]. Next, we consider a system model with three species of fungi that has a common relationship and is not too complicated, and combines the collected data to perform clustering and fitting operations to obtain appropriate values for some correlation coefficients, and then draw a graph of the changes of the three fungi's ability to decompose woody fibers over time and the graph of their relationships.

Then, similarly, we can obtain the quantitative results of the effects of other external factors and own traits on the decomposition ability of specific fungi through experiments. Then, substitute the values of bi, gi, and wi corresponding to the specific fungus into the aforementioned differential equation, and note that our system is under a moderate and constant temperature and moisture, combined with the value limitation in the parameters' definition, so the temperature and moisture influencing factors t and m take the value 0 in this state. At this time, we try to ignore the effect of temperature and moisture changes on the decomposition, and will specifically consider the different mutual constraints and assistance relationships between different fungi in the next question. Hence, it is reasonable to take the value of ai j as 0. Under such conditions, we can make a graph of the changes in the ability of each fungus to decompose wood fibers in this system over time as shown in Figure 1.

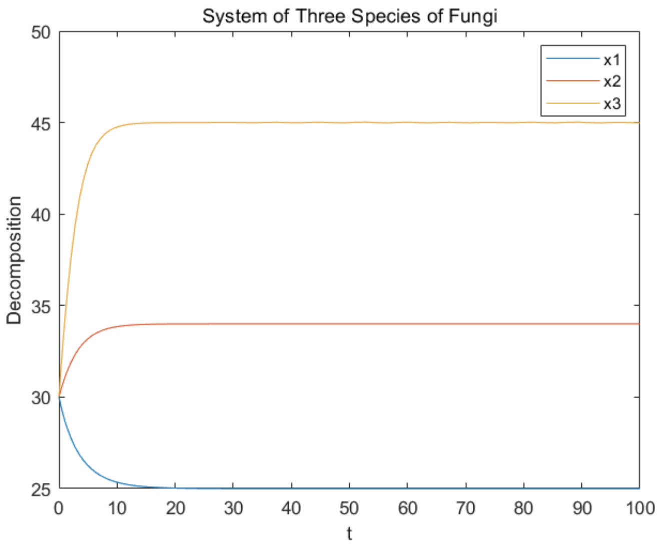

Figure 1 System of Three Species of Fungi

We can find that under this particular situation, the decomposition amount of one type of fungi will gradually decrease to zero over time, while the decomposition capacity of the other two fungi will gradually become constant after a period of rising.

2 The effects of environmental change

We first consider the specific effects of fungal interspecific relationships on decomposition capacity in the absence of environmental influences, and discuss several typical possible scenarios. Then, we add the influence of environment and discuss the results of temperature and moisture on decomposition capacity based on the aforementioned classification of interspecific relationships. Then, we analyze the sensitivity of the environment to rapid fluctuations by suddenly and rapidly changing the temperature and moisture of an otherwise more suitable environment and derive the results.

We then try to analyze the effect of environmental changes on the overall decomposition capacity of the system model of fungi. We obtained the value of the overall decomposition capacity by summing the decomposition capacity of each fungal group at the final moment.

(1) Only Temperature or Moisture Changes

If only the temperature changes, we calculate the final value of the overall decomposition capacity in the change of temperature from low to high and from negative to positive, and make a graph of its relationship with the change of temperature, as shown in Figure 2.

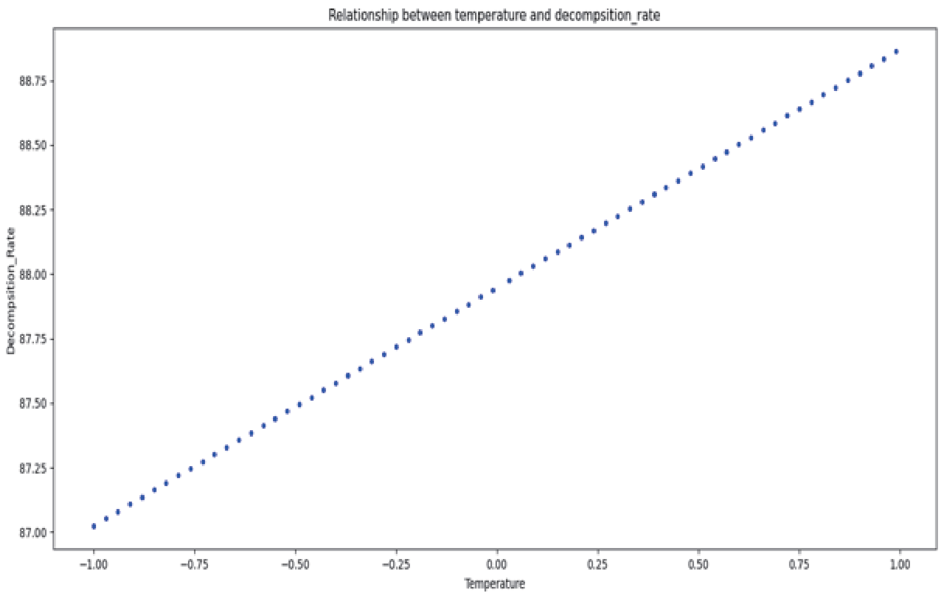

Figure 2: Only Temperature or Moisture Changes

We found that the relationship between the overall decomposition capacity and the external temperature is approximately a linear relationship when only the temperature is varied and the set temperature is increased within a reasonable range. The relationship between the overall decomposition capacity and external moisture is similar to the results for temperature, and we do not show it separately again.

(2) Both Temperature and Moisture Changes

In the following, we consider the overall decomposition capacity affected by simultaneous changes in temperature and moisture. Using the data collected, we take the data values for each of the different temperature and moisture states and draw images named Figure 3 with the value of temperature and moisture as the xy plane and the decomposition capacity of a particular fungus as the z axis. We can see that the decomposition capacity of the fungus continues to rise when the temperature and moisture move in a more positive direction and continues to fall when the temperature and moisture move in a more negative direction.

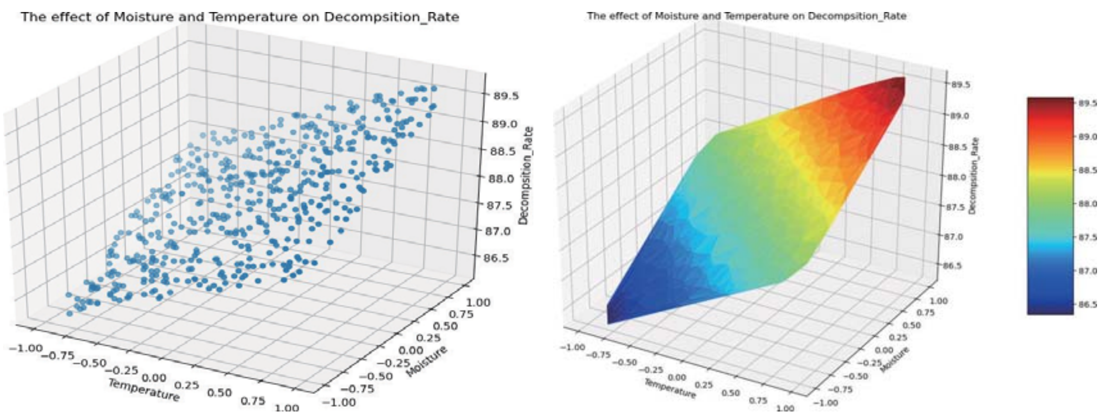

Figure 3. Both Temperature and Moisture Changes-1, Both Temperature and Moisture Changes-2

3. Conclusion

Our model is based on the basic population competition model, named the Lotka-Volterra model, and we extend it somewhat by applying it to represent the dynamic behaviors of decomposition ability over time in a fungal system. We consider a range of factors affecting the system, not only the inherent properties of the fungi themselves such as their hyphal extension rate and moisture tolerance, but also external factors such as the interaction between different species of fungi, and the role of the external environment such as temperature and moisture on the system. By understanding the factors that influence the decomposition ability of fungi through our model, we can have a better understanding of fungal biodiversity and the important role it plays in the Earth's carbon cycle.

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: https://www.pnas.org/content/pnas/117/21/11551.full.pdf.
2. Anna Clocchiatti, S. Emilia Hannula, Marlies van den Berg et al, The hidden potential of saprotrophic fungi in arable soil: Patterns of short-term stimulation by organic amend- ments, Applied Soil Ecology[J], 147, 2020.
3. E. C. Zeeman and M. L. Zeeman, From local to global behavior in competitive Lotka- Volterra systems, Trans. Amer. Math. Soc[M], 355, 2003.
4. A. Cima and J. Llibre, Bounded polynomial vector fields, Trans. Amer. Math. Soc[C],103-104, 1990.