Research progress on dynamic analysis models of soil organic carbon

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Abstract: With the deployment of national environmental protection strategies, the analysis and research of soil organic carbon has gradually become a hot topic in recent years. The dynamic analysis model of soil organic carbon predicts the dynamic changes of soil organic carbon by comprehensively analyzing the organic carbon content and related environmental factors in soil samples. This article summarizes the research progress of soil organic carbon dynamic analysis models in recent years, explores and analyzes the characteristics of current soil organic carbon dynamic analysis models, and puts forward suggestions for future model improvement.

Keywords: soil organic carbon analysis model; Research progress; RothC model; Century model; denitrification-decomposition model

In recent years, the country has made a series of major strategic deployments in areas such as carbon peaking and carbon neutrality, marking the country's high attention to addressing climate change and environmental protection issues. Agricultural carbon sequestration and emission reduction, as one of the important means of reducing emissions and increasing sinks, achieving carbon peak and carbon neutrality goals, plays an important role in climate change response and environmental protection. The dynamic analysis model of agricultural soil organic carbon can quantitatively analyze the content and trend of soil organic carbon, which is of great significance for achieving agricultural carbon sequestration and emission reduction. This article summarizes the progress of soil organic carbon dynamic analysis models in recent years and explores the characteristics of current soil organic carbon dynamic analysis models. Based on these discussions, suggestions are made for future model improvement directions.

1.History of Dynamic Analysis Models for Soil Organic Carbon

1.1 Traditional empirical model stage

In the 1970s and 1980s, researchers mainly relied on traditional soil physical and chemical property data, such as soil organic matter content, soil pH value, soil type, etc. Based on empirical formulas and statistical methods, through statistical analysis of field sampling data, they established soil organic carbon content and distribution patterns to speculate on the content and distribution of soil organic carbon.

1.2Based on process model stage

With the improvement of science, technology, and computing power, researchers have begun to explore the biochemical processes and mechanisms of soil organic carbon dynamic changes. At this stage, soil organic carbon dynamic analysis models are based on the biochemical processes of soil carbon cycling, such as plant growth, litter decomposition, microbial activity, etc. Combining soil physical properties and climate factors, researchers have constructed more comprehensive and detailed simulation models, For example, microbial models, dynamic organic carbon models, etc.

1.3Model Stage Based on Machine Learning

With the improvement of computing power and the arrival of the big data era, soil organic carbon dynamic analysis models based on machine learning and artificial intelligence are gradually emerging. These models use a large amount of soil sample data and meteorological data for training, and through algorithm learning and optimization, can more accurately predict the content and trend of soil organic carbon.

Machine learning models such as Support Vector Machines, Random Forest, and deep learning models such as Neural Networks have been widely used in soil organic carbon analysis.

2.Common Computer Models for Dynamic Analysis of Soil Organic Carbon

Compared with machine learning models, computer models for dynamic analysis of soil organic carbon are more convenient to use and have better reliability in calculation results than empirical formulas. Therefore, they are currently widely used. Below is an introduction to several commonly used computer models.

2.1RothC model

The RothC model is a mathematical model used to simulate the dynamic changes of soil organic carbon. It was developed by the Rothamsted Research in the UK to explain and predict the processes of input, decomposition, and storage of organic carbon in soil.

The RothC model is based on the following key assumptions and principles:

Organic matter input: The model considers organic matter inputs from different sources, including crop residues, vegetation biomass, root exudates, etc.

Decomposition process: The model describes the dynamic process of organic matter decomposition. It considers the effects of factors such as soil temperature, humidity, and soil texture on the decomposition rate of organic matter. The model uses a series of equations to describe the decomposition rate of different organic compounds and the formation of decomposition products.

Storage mechanism: The model considers different forms of organic carbon in soil, including microbial active carbon, stable organic carbon, and unstable organic carbon.

The input parameters of the RothC model include soil type, climate data, vegetation type, and management measures. By inputting these parameters, the model can simulate and predict the dynamic change trend of soil organic carbon.

The RothC model has a wide range of applications, including fields such as farmland management, land use assessment, and carbon cycle research. It can help researchers and decision-makers understand the impact of different management measures on soil organic carbon storage, evaluate farmland carbon emissions and sink capacity, and guide sustainable agricultural development and land resource management.

The characteristics of the Lausanne carbon model are as follows:

① Dataset integration: The Lausanne carbon model utilizes multiple data sources, including observation data, terrain data, climate data, and vegetation data, to provide more comprehensive and accurate input parameters. These datasets are integrated and analyzed through GIS and remote sensing technology to better understand the driving factors and spatial distribution of soil carbon cycling.

② Visualization and prediction functions: The Lausanne carbon model can generate visualized simulation results and prediction charts, helping researchers and decision-makers better understand the dynamic changes of soil carbon. It can provide predictions and assessments of future soil carbon storage, which has important guiding significance for agricultural management and environmental policy formulation.

2.2Century model

The Century model, developed by the University of California, Davis in the United States, is a mathematical model used to simulate and predict soil organic carbon dynamics, widely used in fields such as agriculture, ecology, and land management.

The Century model is based on the following key principles and assumptions:

Organic carbon input: The model considers different sources of organic carbon input, including plant residues, root excreta, vegetation biomass, etc.

Decomposition process: The model describes the kinetic process of organic carbon decomposition. It considers the effects of environmental factors such as temperature, humidity, and soil oxygen content on the decomposition rate of organic carbon, and expresses the decomposition rate of different organic carbon pools through equations.

Carbon storage: The model divides soil organic carbon into several different carbon pools, including fast carbon pools, slow carbon pools, and stable carbon pools. There are processes of carbon transfer and conversion between these carbon pools, and the model considers these processes as well as the equilibrium state of the carbon pool.

Nitrogen cycling: The Century model also considers the cycling process of soil nitrogen, including mineralization and fixation of organic nitrogen. It describes the interactions and effects between carbon and nitrogen.

The input parameters of the Century model include soil type, climate data, vegetation information, and management practices. By inputting these parameters, the model can simulate and predict the dynamic change trend of soil organic carbon, and evaluate the impact of different management measures on soil carbon storage and nitrogen cycling. At the same time, the Century model has a wide range of applications, including fields such as farmland management, forest ecosystems, and land use change. It can help researchers and decision-makers understand the impact of different management practices on soil carbon and nutrient cycling, guide sustainable agricultural development and land resource management, and assess the carbon storage and emissions of ecosystems.

2.3 DNDC model

The DNDC model (DeNutrition DeComposition) is a widely used mathematical model for simulating processes such as nitrogen cycling, greenhouse gas emissions, and soil organic matter dynamics in farmland and soil ecosystems. This model was first developed by scholars from Washington State University in the United States and has been widely applied globally.

The DNDC model is based on the following key principles and assumptions:

Nitrogen cycle: The model simulates the nitrogen transformation process in soil, including nitrogen mineralization, nitrification, denitrification, etc. It considers the effects of environmental factors such as soil temperature, humidity, and organic matter content on nitrogen cycling rate, and describes the transformation process of different nitrogen compounds.

Carbon cycle: The DNDC model also considers the decomposition and storage process of soil organic matter. It describes the decomposition rate of organic matter and the formation of decomposition products, and simulates the carbon cycling process based on factors such as soil temperature and humidity.

Greenhouse gas emissions: This model can estimate the emissions of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. It considers the effects of nitrogen cycling, carbon cycling, soil moisture, temperature, and other factors on greenhouse gas production and emissions.

The input parameters of the DNDC model include soil properties, climate data, farmland management measures, and fertilization conditions. By inputting these parameters, the model can simulate and predict key indicators such as nitrogen cycling in farmland, changes in soil carbon storage, and greenhouse gas emissions.

The DNDC model is widely used in the fields of agricultural ecology, soil science, and environmental science. It can help farmers and decision-makers evaluate the impact of different farmland management practices on nitrogen utilization efficiency, provide information for reducing greenhouse gas emissions and improving soil quality. This model can also be used to develop farmland management strategies and promote sustainable agricultural development.

3. Future Development Trends of Soil Organic Carbon Models

Model improvement: Traditional models usually assume that the decomposition rate of soil organic carbon is constant, while new models need to consider the effects of environmental factors such as soil moisture, temperature, and oxygen on the decomposition rate. In addition, factors such as vegetation input, soil carbon sequestration capacity, and soil microbial activity should also be considered to more comprehensively describe soil carbon cycling.

Data support: Soil carbon quality, soil moisture, and soil type data obtained through high-resolution remote sensing images, LiDAR scanning, and other technologies can provide more accurate input data for the model.

Scale conversion: By combining Geographic Information System (GIS) technology with soil carbon models, spatial distribution maps of soil carbon dynamics can be established within a regional range, and accurate assessments of carbon sinks and greenhouse gas emissions can be made.

Comprehensive evaluation: The research on soil carbon models has gradually expanded from a single carbon cycle process to a comprehensive evaluation of the overall function of soil ecosystems. It is necessary to comprehensively consider the interaction between soil carbon and other ecological factors (such as vegetation type, land use mode, etc.), as well as the response and impact on climate change.

Future research in this field needs to continuously improve the accuracy and applicability of models, and strengthen the integration with field observation data to better understand and manage soil carbon cycling, providing scientific support for sustainable agriculture and ecological environment protection.

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