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Advances in Ecological Stoichiometry in Soil Research

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Abstract

Soil carbon (C), nitrogen (N), and phosphorus (P) characteristics can be used to measure soil quality and are also an important basis for ecological restoration. Since ecological stoichiometry was proposed, it has been increasingly used in various fields of natural science research. This article briefly describes the development process and current status of ecological stoichiometry in soil research.

Keywords

Ecological Stoichiometry; Organic Carbon; Nitrogen; Phosphorus.

1. Introduction

With the rapid development of biological sciences, Schindler[1]applied the principles and methods of stoichiometry to the field of ecology in 1862, and proposed the Liebis law of minimum quantity, which considers that all the living organisms need Among the essential elements, the smallest essential element is the element that restricts the growth of organisms. In 1925, Lotka [2] combined the laws of thermodynamics with biology, and on this basis produced many basic theories of ecological stoichiometry, the most famous of which is the Redfield ratio [3]. This theory points out that there is a fixed ratio of C, N and P elements in marine zooplankton: 106:16:1. In 1986, William A. Reiners [4] first linked ecology with stoichiometry. By the 1990s, scientists had carried out a lot of research based on this theory and achieved a series of results. In 2000, Elser formally proposed the concept of ecological stoichiometry [5]. In 2002, the publication of Sterner's "Ecological stoichiometry" marked that ecological stoichiometry has become a systematic discipline. As a rapidly developing field, ecological stoichiometry mainly starts with elements, studying the balance between chemical elements from the molecular level to the global level and the interaction between organisms and the environment [6-7], ecological stoichiometry will Ecology, physics and chemometrics are linked together, and its temporal and spatial dynamics have been successfully used to study nutrient limitation [8-9], community dynamics [10], microbial nutritional status [11], symbiosis [12], nutrient Utilization efficiency [13] and biogeochemical cycle [14]. Chinese scholars have also carried out a large number of researches and achieved many results from various levels, fields, and different scales such as cells, species, communities, and ecosystems. For example, scholars have launched many reviews and discussions on the theory and application of ecological chemometrics. Some scholars have studied the relationship between nitrogen, phosphorus and climate based on the relationship between ecological stoichiometry and environmental

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protection [15], and some have studied farmland ecological stoichiometry based on guiding production.

2. Soil carbon, nitrogen and phosphorus

Ecological stoichiometry was first used in aquatic ecosystems, and later in terrestrial ecosystems by Walker and Adams [16-17]. Soil is an important part of the terrestrial ecosystem. Its nutrient accumulation and circulation are affected by vegetation, climate, human activities and other factors. Soil ecological stoichiometry is revealed by studying the balance and restriction relationship between soil C, N, and P elements. Soil nutrient cycling and limitation, measuring soil quality.

Soil organic carbon

A series of pollution problems arising from the rapid development of modern society seriously threaten the ecological environment. Among them, global warming caused by the greenhouse effect caused by excessive emission of carbon dioxide has been paid attention to by governments, experts and scholars all over the world. As the largest carbon reservoir of terrestrial ecosystems, soil is an important part of the global carbon cycle and is closely related to carbon dioxide emissions. Regarding the soil carbon pool, related scholars have carried out a lot of research [18-19]. Soil carbon pool mainly includes organic carbon pool and inorganic carbon pool, which account for about 2/3 and 1/3 of soil carbon pool respectively. Soil organic carbon can directly reflect the level of soil quality, and changes in its content will have a significant impact on the structure, function and sustainability of terrestrial ecosystems. As early as the 1960s, foreign scholars had studied soil organic carbon storage, but most of them were estimated based on soil profile data [20]. In the 1980s, scholars began to use statistical methods to estimate [21]. In the 1990s, the development of 3S technology provided more efficient and accurate methods in terms of organic carbon storage estimation and spatial distribution [22]. Studies have shown that C is mainly derived from animal, plant and microbial residues, secretions, excreta, and soil humus [23]. It mainly exists in soil aggregates in the form of gel film, which promotes the formation of soil aggregate structure and maintains the stability of soil structure. , It plays a positive role in improving soil water and heat conditions, improving soil erosion resistance, and reducing soil erosion. The content of C is the balance between the input of animal and plant residues entering the soil and the loss of microbial decomposition. It is one of the indicators for evaluating soil quality and can reflect the availability of plant nutrients [24]. The content of C is affected by natural and human factors including vegetation, climate, parent material, and land use changes. Among them, land use changes change the nutrient cycle in the soil by affecting vegetation types. The study of Tiessen [25] et al. showed that C was reduced by 30% to 50% after the conversion of grassland to farmland. Grandy [17] et al. pointed out that the C content tends to increase after farmland is restored to forest land.

3. Soil nitrogen and phosphorus

Nitrogen is not only the material basis of soil fertility, but also an essential element that affects the growth of vegetation. It mainly affects the photosynthesis of plants. The nitrogen cycle in the soil is mainly composed of biological nitrogen fixation, nitrogen mineralization, and available nitrogen release. Plants synthesize their own protein molecules by absorbing nitrate nitrogen in the soil. Therefore, nitrogen is also commonly used to measure ecology. System productivity. Soil nitrogen is divided into organic nitrogen and inorganic nitrogen, but mainly exists in the form of organic nitrogen. Organic nitrogen of different chemical forms has different nitrogen availability. Organic nitrogen, like C, uses organic matter as the carrier. The content of organic matter and the rate of mineralization and decomposition will affect C and nitrogen. A large number of studies have shown that the changes in soil nitrogen and C are synchronous,

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showing a high correlation relationship. Soil types and land use methods will affect the content and distribution of soil organic nitrogen. Different land use methods enter the soil with different plant residues, and different land management measures will affect the mineralization, decomposition, absorption and utilization of soil nitrogen, making it different under different land use methods [26]. Research by Zhang Yangyang et al. pointed out that under the same soil depth, the N content shows: woodland>grassland>farmland[27]; Zhang Yubin[28] also found that the farmland has the smallest N content under different land use patterns in the Yellow River Basin. The study by Gong Jie et al. found that the sloping farmland was restored to grassland forest land, and the soil N content increased significantly [29]. Compton [30] et al. found that after the forest was reclaimed into farmland, the soil N content was reduced by 8%.

Phosphorus is one of the essential nutrient elements in plant growth. It participates in the composition of many biological enzymes, is related to a variety of respiratory metabolism processes and enzymatic reactions, and has an impact on biological growth [31]. Soil phosphorus mainly comes from rock weathering and has poor mobility in the soil. As a regulating element in plant growth and metabolism, soil phosphorus can play a role in maintaining the balance of the ecosystem to a certain extent. Soil phosphorus is divided into organic phosphorus and inorganic phosphorus. The available soil phosphorus that can be absorbed and utilized by plants mainly comes from active organic phosphorus. Therefore, although organic phosphorus cannot be directly absorbed and utilized by plants, it still significantly affects the nutritional status of plants and soil fertility. Therefore, phosphorus has also become one of the indicators for evaluating soil quality.

4. Soil ecological stoichiometric ratio

The discovery of the "Redfield" ratio has caused a large number of scholars to study C:N:P [32-33] Compared with marine ecosystems, the biodiversity of terrestrial ecosystems is more complex, and the stoichiometric characteristics of soil ecology are also more complex. Soil C:N:P is used to measure the cycle of C, N, and P in the soil, although scholars at home and abroad have studied soil C:N:P at different scales and found that the ratio of carbon, nitrogen and phosphorus has a relatively stable ratio. Characteristics, such as the global 0-10cm surface soil C:N:P stabilized at 186:13:1 [34], and the Chinese soil C:N:P stabilized at 60:5:1 [35]. However, some scholars [36] pointed out that this relatively stable feature will only appear under certain restrictions. This is because regional hydrothermal conditions and soil forming conditions will affect the content of soil C, N, and P. For example, high temperature and heavy rain will accelerate phosphorus leaching and high weathering. The lack of phosphorus in the soil will cause C:P and N:P. The value becomes larger, resulting in different C:N:P ratios in different places. C:N and C:P can be used to measure the rate of mineralization and decomposition of organic matter and phosphorus, respectively. When the C:N is low, it means that the mineralization and decomposition rate of the soil is faster, which is not conducive to the accumulation of organic matter; when the C:P is low, it is conducive to the decomposition of organic matter and increase the effective phosphorus content. Soil N:P is mainly used to measure the limiting effect of nitrogen and phosphorus.

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