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Review of progress in soil inorganic carbon research

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Abstract. Soil inorganic carbon is one of the main carbon banks in the near-surface environment, and is the main form of soil carbon library in arid and semi-arid regions, which plays an important role in the global carbon cycle. This paper mainly focuses on the inorganic dynamic process of soil inorganic carbon in soil environment in arid and semi-arid regions, and summarized the composition and source of soil inorganic carbon, influence factors and soil carbon sequestration.

1. Introduction

In recent years, the concentration of atmospheric CO₂ has been increased due to human activities, It has caused a series of environmental problems such as global warming and greenhouse effect, which has made global carbon emissions control the focus of international attention. Among them, the soil "carbon source" and "carbon sink" function play an important role in global carbon cycle research[1]. A large number of studies have shown that soil CO₂ negative flux is detected in the desert regions of many countries, such as the United States and China. Its magnitude is around C 100 g·m⁻²·a⁻¹[2]. Such a large amount of carbon negative flux can be produced mainly due to the soil inorganic carbon cycle process in desert areas which have sparse vegetation, poor soil and weak life processes.

Wohlfahrt G L studied the soil in the American desert using high temperature sterilization to remove the biological effects of soil. And it turns out, after sterilization treatment, there is still a very obvious CO₂ negative flux which proves that soil CO₂ absorption is an inorganic process[3]. In the domestic, Ma Jie also used the same method to verify that the inorganic carbon cycle of saline soil in arid and semi-arid regions produces a large amount of CO₂ negative flux, this indicates that the soil inorganic carbon in arid semi-arid region has the potential of "carbon sink" in the process of modern carbon cycle[4]. However, the current understanding of soil carbon cycle mechanism is not comprehensive enough to understand the transmission and exchange conditions and influencing factors of each source and sink[5]. Therefore, studying the formation mechanism of soil inorganic carbon and exploring the carbon sequestration is not only has a better understanding of the dynamic circulation of soil carbon storage in arid regions, but also has great significance for the study of global change.

2. Composition and source of soil inorganic carbon

Soil inorganic carbon is one of the main carbon storage in near-surface environment, which reserves is second only to soil organic carbon, accounting for 38% of the global total[6]. Soil inorganic carbon is



mainly refers to the parent rock soil carbonate formed in the weathering process of silicate carbon, which has very high accumulation rate, and easily affected by atmosphere, water, rocks, etc, is the main form of soil carbon pool in arid and semi-arid region. The soil inorganic carbon includes the CO_2 of the gas phase, the liquid phase solution containing HCO_3^- and CO_3^{2-} and the carbonate in solid phase. However, in the case of good drainage conditions and the soil $\text{pH} > 6.5$, the amount of inorganic carbon in the soil gas phase and the liquid phase is negligible relative to the solid phase, and the solid phase is the main composition of soil inorganic carbon[7]. According to the source, the soil carbonates include the primary carbonate and the pedogenic carbonate. Primary carbonate is derived from a form of soil or parent rocks, which is preserved by an unweathered soil and has not been exchanged with the soil environment. Pedogenic carbonate is a product of the parent carbonate, which are dissolved in the atmosphere and water by weathering into soil[8].

The inorganic carbon balance process of $\text{CO}_2(\text{g})\text{-CO}_2(\text{aq})\text{-HCO}_3^-(\text{aq})\text{-CaCO}_3(\text{s})$ is commonly found in soil. The CO_2 from soil respiration and atmosphere are dissolved in water, at the same time, hydrolysis of bicarbonate is converted into pedogenic carbonates with other salts such as Ca^{2+} and Mg^{2+} . Yang Lifang created five kinds of inorganic carbon formation mechanism model to describe the soil secondary carbonate formation, there were reduced genetic model, ascending genetic model, autochthonous model, biogenic model and frozen genetic model, and suggests that the formation of carbonate is generally produced by a model or model of the above[9]. Gile also established corresponding models for the formation and morphology of carbonate in desert climate, who suggested that the development of soil carbonate would be in five stages, from filaments to carbonate sheets would take tens of thousands of years to form[10]. There are many mechanisms of soil secondary carbonate formation, but the most basic reason is the limited depth of soil water movement based on carbonate deposition and the higher seasonal evapotranspiration[11].

3. The influence factors of soil inorganic carbon distribution

The reserves and distribution of soil inorganic carbon are related to soil moisture, soil type, salinity degree and soil temperature. Especially in arid and semi-arid areas with vegetation sparse, along with the changes in the state of soil moisture and CO_2 partial pressure, the dissolution and deposition of inorganic carbon in time and profile space reversible phenomenon is very obvious. In arid and semi-arid regions there have a high temperature and rainfall in summer, and this lead to the mineralization of soil organic matter and biological respiration rate is higher, so as to improve the partial pressure of CO_2 in the soil air. CO_2 and soil water to form carbonic acid solution, and it can dissolve part carbonate. After summer, when the soil water evaporates, the bicarbonate is deposited into carbonate[12].

Xie Huailiang et al. studied found the soil carbon will be obviously leached as the water moves downwards in the process of irrigation in the dry area. Whether the soil of oasis farmland or undeveloped soil has a different degree of carbon loss, especially the inorganic carbon leaching volume is larger[13]. The depth of the soil water movement is limited, so it can drive down the number of inorganic carbon transport will also restricted, thus lead to the inorganic carbon content in the profile distribution has a great deal of temporal and spatial variability. Wang Yugang et al. found that the inorganic carbon distribution of saline-alkali soil section in arid area varies with the depth of soil layer, and its content is different. Nearly 80% of inorganic carbon is stored below 1 m, and 50% inorganic carbon is stored below 3 m[14]. The inorganic carbon content of different soil types can vary widely, Gong Lu et al. studied the content of inorganic carbon in four different types of soil in Xin Jiang, the results showed that the inorganic carbon content of the sand soil was significantly higher than that of the desert soil, brown desert soil and salt soil[15]. Liu Shuli et al. investigated the soil inorganic carbon reserves of four kinds of alpine grassland in Qing Hai province, and the results showed that different grassland types have different inorganic carbon reserves, which have the highest is temperate grassland and the lowest is alpine meadow[16]. Yan An studied the effect of soil salinity on the vertical distribution of soil carbon in saline soil in arid areas. The results showed that salt was negatively correlated with inorganic carbon content and density in the whole soil profile[17]. In fact,

the effect of environmental factors is that it can affect the carbon balance in soil, and control the fixation and loss of soil inorganic carbon at different time and space scales[18].

4. Soil carbon sequestration studies

Soil inorganic carbon is easy to decompose under environmental conditions, which is directly related to whether the process is a new source of greenhouse gas emission under environmental changes. To facilitate the understanding of soil carbon sequestration mechanism, isotope techniques and mathematical model is established to quantitatively study the soil carbonate leached-precipitation reaction and the influence of natural factors and human activities on the process in recent years. It is helpful to know the soil carbon sink process in arid and semi-arid regions objectively and accurately. Magaritz et al. describe the development in the pleistocene marl irrigation soil and adjacent to the irrigation soil carbonate of stable isotope research shows that after 40 years of irrigation, the net carbon loss of the upper total carbonate of soil section was increased, but the carbonate carbon was increased in the core of the soil[19]. Qin Xiaoguang et al. used biogeochemical models to study the effects of climate change on the carbon pool effect of the loess, and proved that the loess carbon bank is mainly secondary carbonate carbon sink, which is a foreign exchange of atmospheric CO₂ under natural conditions[20]. Based on CO₂(g)-CO₂(aq)-HCO₃⁻(aq)-CaCO₃(s) soil carbon balance equation, Zhang Lin et al. determined the value of δ¹³C of soil carbonate, and the value of soil CO₂ δ¹³C and the parent carbonate δ¹³C, finally quantified the amount of soil CO₂ in the process of recrystallization[21].

5. Conclusion

The formation mechanism of soil inorganic carbon has gradually become clear as the soil inorganic carbon has been studied extensively. Especially in arid and semi-arid regions, the inorganic circulation process of soil carbon has the potential of carbon sequestration. It is due to long-term human activities and environmental factors that causes the dissolution of soil secondary carbonates and the repeated process of recrystallization, thus affecting the fixation and transfer of soil carbon. The change of soil inorganic carbon bank is closely related to the global carbon cycle. It will be an important direction for future inorganic carbon research to fully understand the carbon sequestration mechanism of soil inorganic carbon and quantify its transformation and strengthen the application of isotope technology such as ¹³C, ¹⁸O and ⁴⁵Ca[22].

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