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Analysis of Causes, Control Measures and Development Trend of Salinization of Cultivated Land

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Abstract

Saline-alkali land is a special soil type, whose high salinity and alkali content pose a serious threat to crop growth and is one of the major challenges facing the sustainable development of global agriculture. This paper aims to discuss the safety of the key technology of comprehensive improvement of saline-alkali land, and provide scientific basis for effective treatment of saline-alkali land through in-depth analysis of soil saline-alkali characteristics, specific application and development trend of the improvement technology.

Keywords

Cultivated land, salinization, treatment measures.

1. Introduction

Salinization refers to a phenomenon in which the concentration of soluble salts (Na^+、Cl^-、SO_4^{2-}) or sodium ions in soil is abnormally increased, leading to structural damage and a decrease in soil fertility. The global salinized land area is about 950 million hectares, accounting for more than 20% of the total cultivated land [1]. The total saline-alkali land area in China is about 100 million hectares, of which 35 million hectares of potential arable land can be developed and utilized [2]. Salinization not only reduces crop yields, but also increases regional water scarcity and ecological vulnerability. Therefore, it is of great significance to analyze the causes of salinization, optimize the treatment technology and quantify the productivity potential for realizing the sustainable utilization of land resources.

2. Cause Analysis of Salinization of Cultivated Land

The formation of saline-alkali land is the result of the interaction of natural factors and human factors. Natural factors mainly include climate, terrain, soil texture and so on. In arid, semi-arid and sub-humid areas, due to the lack of precipitation and large evaporation, the salt in the soil is difficult to discharge, and gradually accumulate and cause salinization. In addition, the fluctuation of terrain will affect the flow path and distribution of surface water and groundwater, and the groundwater level in flat areas is higher, which provides conditions for the formation of saline-alkali land. In terms of soil texture, clay soil has a strong water retention ability, which is conducive to the lasting accumulation of salt [3]. Human factors mainly include excessive reclamation, unreasonable irrigation, etc., these activities will aggravate the soil salinization process.

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2.1. Natural driving factors

Evaporation in arid and semi-arid areas is much higher than precipitation, resulting in the accumulation of salt along with the surface of the capillary water. For example, the annual evaporation of the Tarim Basin in Xinjiang reaches 2000-3000 mm, and the precipitation is less than 100 mm. In arid and semi-arid regions, precipitation is scarce but evaporation is intense, and the salt in the soil accumulates in the surface of the soil with the evaporation of water. For example, the annual precipitation in the northwest of China may only be tens to hundreds of millimeters, while the evaporation can reach thousands of millimeters, which is very easy to lead to soil salinization. In some areas, the climate is relatively dry and the humidity in the air is low, which will also accelerate the evaporation of soil water, thus aggravating the soil salinization process. On the other hand, in the monsoon area (such as the North China Plain), the concentrated precipitation in summer is briefly leaching salt, but the evaporation is intense in the dry period of winter and spring, forming a dynamic process of "salt comes with water, salt goes with water".

Closed or semi-closed basins (such as low-lying areas of the Huang-Huai-hai Plain) are difficult to leach and discharge salt due to poor drainage and shallow groundwater level (<2 m). In low-lying farmland near rivers or lakes, due to the low-lying terrain and relatively high groundwater level, groundwater is easy to rise to the surface through soil capillary action [4]. If the groundwater salt content is high, the salt will remain in the soil surface with the evaporation of water, resulting in soil salinization. Coastal areas are vulnerable to saltwater intrusion, caused by sea level rise or over-exploitation of groundwater, which can penetrate the land, and the salt content of the seawater is very high, and once it invades the soil of farmland, it will rapidly increase the salt content of the soil.

2.2. Anthropogenic intensification

1. Unreasonable irrigation

Flood irrigation led to the rise of groundwater level (for example, the water level in some areas of Ningxia Yellow River irrigation area rose by 1.5 m/ year), and the secondary salinization accounted for 30% of the area. 15% of the world's irrigated areas use water with salinity >1.5 dS/m, adding 2 million hectares of salinized land each year. The amount of irrigated water per mu in the North China Plain exceeds the water demand by 40%, causing the groundwater level to rise below the critical depth (1.5 m).

2. The drainage system is not perfect

Lack of dark pipe salt drainage or shaft drainage projects, salt retention in the root zone (such as Songnen plain saline land). There are many problems in the farmland drainage system in some areas of our country, such as aging facilities, low design standards, lack of maintenance, etc., resulting in a significant decrease in drainage capacity [5]. At the same time, the problems such as unscientific division of planning area and unreasonable arrangement of water conveyance system also seriously affect the drainage effect of farmland. In addition, the management level of farmland drainage system in some areas is relatively low, the management means lag, and the management system is not perfect, which further aggravates the problem of poor drainage.

The drainage system is not perfect, resulting in rain and groundwater cannot be discharged in time, making the groundwater level continue to rise. The high groundwater level makes the soil in a long-term overwent state, and the permeability becomes poor, affecting the respiration and nutrient absorption of crop roots. At the same time, the salt in groundwater rises to the surface with the capillary action, and gradually accumulates in the soil, forming salinization or salinization. In the case of poor drainage, the salt in the soil is difficult to be removed by leaching. As water evaporates, salt gradually accumulates in the soil surface, resulting in an increase in soil salinity. This salt accumulation not only affects the normal growth of crops, but also may

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lead to soil compaction and fertility decline, further worsening agricultural production conditions.

3. Fertilizer abuse and vegetation destruction

The application of chemical fertilizers is one of the important means to improve crop yield, but excessive application of chemical fertilizers, especially those containing chloride ions (such as potassium chloride), will significantly increase the content of base ions in the soil, and excessive reclamation will destroy the desalting function of native vegetation (such as tamarisk, tamarisk) [6]. The accumulation of these base ions in the soil will destroy the acid-base balance of the soil, reduce the permeability of the soil, and affect the normal growth of crops.

Native vegetation plays an important role in maintaining soil water and salt balance. For example, saline-tolerant plants such as tamarisk and Tamarisk can absorb salt from the soil through their roots and store it in the body, thus playing a role in desalting. However, with the continuous development of agricultural production, the phenomenon of over-reclamation and vegetation destruction is becoming more and more serious. The loss of these native vegetation not only weakens the desalting function of the soil, but also makes the soil more vulnerable to salt accumulation. Especially in the case of imperfect drainage system, the salt in the soil can not be effectively discharged, which is more likely to lead to salinization or salinization of cultivated land.

3. Salinized Farmland Management Measures

3.1. Traditional improved technology

1. Water conservancy project

The measures of water conservancy project are one of the important means of salinized farmland management. Its core is to reduce the groundwater level and prevent salt from accumulating on the surface with the rise of groundwater through reasonable water conservancy facilities construction and irrigation and drainage management. Specific measures include irrigation and salt washing and drainage. Irrigation washes water into saline-alkali fields to dissolve the salt in the soil, and then washes the salt out through infiltration and removes it through drains. This measure can not only meet the water needs of crops, but also effectively adjust the soil salt concentration [7]. Timely drainage can reduce the water table and prevent saline groundwater from running to the surface, thereby reducing soil salt accumulation and surface salt return. At the same time, drainage can also accelerate the removal of salt from rainfall, irrigation and washing processes.

2. Agricultural measures

Agricultural measures improve soil environment by optimizing farming patterns and reduce salinity hazards. Soil leveling and deep tillage Reduce local salt spots by leveling the land, and loosen the soil by deep tillage to destroy salt crusts and increase soil permeability. For example, Baocheng City in Jilin Province significantly reduced surface salt accumulation through deep ploughing of 40 cm combined with multiple ploughing. Rotation and intercropping Use of salt-tolerant crops (such as sweet sorghum and sunflowers) with common crops, or intercropping of legume green manure, to enhance soil organic matter. Zhang Jinhai promoted sweet sorghum cultivation in Shandong, producing 7 tons per mu while improving soil structure. Salt-tolerant crop selection Salt-tolerant varieties are cultivated by molecular breeding techniques [8].

3.2. Modern ecological restoration technology

1. Microbial remediation

Microorganisms can repair saline-alkali land by improving crop salt tolerance and changing physical and chemical properties of saline-alkali land. Since rhizosphere microorganisms have been shown to increase plant tolerance to stress, many beneficial microorganisms that help

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plants cope with salt stress have been isolated and used to increase crop yields in saline-alkali soils. There are many ways for microbial improvement of saline-alkali land, and the common method is to make microbial fertilizers or microbial preparations, which can be directly applied to the soil or used in combination with fertilizers. In addition, studies have shown that some strains can be applied to crop seeds before sowing to enhance the growth ability of plants under saline conditions or improve the germination rate of seeds, indicating that microorganisms can reduce the negative effects of salt stress on plants.

In fact, the repair effect of single strain on saline-alkali soil is limited, and the use of complex bacterial community is a more economical and efficient method. The improvement effect of microbial community on soil has been proved long ago. Exogenous microbial flora can reduce the salt content in soil, restore the soil hierarchy, and make it more suitable for plant growth. Adding microbial agents during crop planting can improve soil physical and chemical properties, increase soil organic matter content, and decrease soil pH and salt content [9]. In addition, fish culture in the embankment can significantly increase the activity of various organic enzymes in the soil, the number of humus and other microorganisms, and studies have found that after the decomposed straw is returned to the field, similar effects appear.

Microbes are not the only ones playing a role in the process of using microbes to repair saline soil. The microbial community with the potential of saline-alkali land restoration is used for saline-alkali land restoration. Such microbial community will change the soil structure, and eventually form an ecological cycle in which microbial groups - microorganisms change the soil microenvironment - microorganisms and soil co-evolve. Therefore, regulating the interaction between microorganisms and soil is an effective strategy to cope with saline-alkali stress, and it is also a key breakthrough for saline-alkali land restoration.

2. Phytoremediation technology

Plant growth has an effect on soil water and salt balance, and can effectively reduce soil soluble salt content by absorbing water and reducing evaporation. The improvement process of saline-alkali land depends on the replacement of excess sodium ions (Na^+) by calcium ions (Ca^{2+}) during cation exchange and the migration of Na^+ out through irrigation water. However, the solubility of $CaCO_3$ in saline-alkali soil is low, which cannot provide enough Ca^{2+} for improvement. Through root respiration and decomposition of organic matter, salt-tolerant plants can increase CO_2 concentration in the root zone, and some plant roots can release protons (H^+) into the root zone to accelerate the dissolution of $CaCO_3$, thus promoting the Ca^{2+} replacement of Na^+ [10]. Therefore, it is particularly important to use saline-alkali tolerant plants for plant restoration of saline-alkali land. Planting saline-tolerant plants can increase plant diversity and improve soil characteristics in saline-alkali land, thus achieving the purpose of improving saline-alkali land.

Although the ability of plants to absorb and remove salt by themselves is limited, their role in reducing the accumulation of salt in the soil cannot be ignored. Studies have shown that different regions and different species of plants differ in how well they absorb salt from the ground. When the soil moisture reaches a certain level, the above-ground part of the plant has the best effect of carrying away salt and Na^+. In addition, plant residues are important sources of soil organic matter and contribute significantly to the increase of soil organic matter content. In soil, the humification process of plant residues and the adsorption of soil colloids effectively increase the content of soil organic matter, and microorganisms play a key role in this process to promote the transformation of plant residues into soil organic matter. In saline-alkali soil, a large amount of H^+ in plant root exudates is released into the soil, resulting in a decrease in soil pH value, which may indirectly affect the community structure and activity of soil microorganisms, as well as the absorption and utilization of nutrient elements by plants. At the same time, when an electrochemical gradient is formed at the soil-root interface, cations are

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transported across the membrane under the action of membrane potential, which promotes the release of net H^+ into the soil along with membrane depolarization.

3. Intelligent monitoring

In the treatment of salinized farmland, remote sensing technology and Internet of things sensors can be combined to monitor key environmental parameters such as soil conductivity in real time, and regulate irrigation strategies, which can effectively reduce soil salt content, improve soil structure, and improve soil fertility. The intelligent monitoring system can monitor the soil environmental parameters of saline-alkali land in real time, and find the risk areas and potential problems of soil salinization in time. The early warning system can predict the development trend of salinization and provide strong support for taking timely prevention and control measures. In general, the application of intelligent monitoring system can significantly improve the efficiency and effect of saline-alkali land management [11]. Through real-time monitoring and precise regulation, water resources waste and excessive use of fertilizers and pesticides can be reduced, and governance costs and environmental risks can be reduced. At the same time, the intelligent monitoring system can also provide long-term and continuous data support for the treatment of saline-alkali land, and provide a strong basis for the development of scientific and reasonable treatment programs.

4. Development Trend of Saline-alkali Land Improvement Technology

4.1. Interdisciplinary integration and technological innovation

With the continuous development of science and technology, saline-alkali land improvement technology will pay more attention to interdisciplinary integration and technological innovation. By combining environmental science, material engineering, agricultural ecology and other multidisciplinary knowledge and technical means, we can develop more efficient, environmental protection and economic saline-alkali land improvement methods. For example, the application of nanotechnology in saline-alkali soil improvement can improve the ion exchange efficiency of chemical amendments and the adsorption capacity of pollutants. The application of microbiome engineering in saline-alkali soil improvement can accelerate the restoration of soil microecology and increase the accumulation rate of organic matter.

4.2. Development of precision agriculture and smart agriculture

Precision agriculture and smart agriculture will become one of the important directions of saline-alkali land improvement in the future. Through the use of advanced technological means such as the Internet of Things, big data and artificial intelligence, accurate monitoring and management of saline-alkali land can be achieved to improve the intelligent level and efficiency of agricultural production. For example, the digital farmland management system can real-time monitor soil moisture, salt and other parameters as well as crop growth conditions and other information to provide scientific basis for precision irrigation, fertilization and other agricultural measures; Through intelligent equipment such as drones and robots, agricultural operations such as sowing, fertilizing and weeding can be automated to reduce labor costs.

4.3. In-depth concept of environmental protection and sustainable development

With the deepening of the concept of environmental protection and sustainable development, the future saline-alkali land improvement technology will pay more attention to environmental protection and sustainability. Ecological restoration, circular agriculture and other green development models can reduce environmental pollution and damage to achieve sustainable development of agricultural production. For example, in the process of saline-alkali land improvement, the soil environment can be improved by planting saline-alkali tolerant plants

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and green fertilizers. In the process of agricultural production, crop rotation and intercropping can be adopted to improve the efficiency of land use and reduce production costs.

4.4. Increase of policy support and capital investment

Government policy support and capital investment are important guarantees to promote the development of saline-alkali land improvement technology. In the future, the government will increase the research and development and promotion of saline-alkali land improvement technology, formulate more complete policy measures and financial support system, and encourage enterprises and social capital to participate in saline-alkali land improvement work. At the same time, the government will also strengthen the supervision and evaluation of saline-alkali land improvement technology to ensure its safety and effectiveness.

5. Conclusion

Salinization of cultivated land is a complex phenomenon of land degradation, the causes of which include both natural and man-made aspects. The natural factors mainly involve climatic conditions, landform features and soil texture. The human factors mainly include unreasonable irrigation, excessive fertilizer application and improper land use. In order to solve the problem of salinization of cultivated land, various treatment methods such as water conservancy engineering measures, agricultural biological measures and chemical improvement measures can be adopted to optimize the structure and fertility of salinized soil, and then improve the yield and quality of crops. At the same time, the driving force of technological progress, the enhancement of policy support and the pulling force of market demand are driven by the research and development of new restoration materials, the improvement of ecological compensation policies and the balance mechanism of arable land. In-depth research on the action thresholds and synergies of various improvement technologies, the interaction mechanism between improvement measures - soil system - plant growth, and the multi-interface regulation mechanism of salt migration and transformation, and the formation of a three-dimensional collaborative governance model of "technology iteration - policy guarantee - market drive".

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