ISSN: 2710-0723

Research on Saline-alkali Land Improvement Technology and Safety

Yan Li[1,2,3,4], Nan Lu[1,2,3,4], Yuhu Luo[1,2,3,4]

[1] Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710021, China

[2] Shaanxi Agricultural Development Group Co., Ltd, Xi'an 710075, China

[3] Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources, Xi'an 710021, China

[4] Key Laboratory of Cultivated Land Quality Monitoring and Conservation, Ministry of Agriculture and Rural Affairs, Xi'an 710021, China

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. The origin and characteristics of saline-alkali land and its influence on agricultural production are summarized in this paper. The application and safety evaluation of engineering improvement, chemical improvement, agricultural measures and smart agriculture in saline-alkali land improvement were analyzed. The development trend of saline-alkali land improvement technology is prospected, and corresponding conclusions and suggestions are put forward. The research shows that saline-alkali land can be gradually transformed into high-yield and stable farmland through multidisciplinary integration and local adaptation technology, but it still needs to strengthen research in long-term monitoring, cost optimization and ecological balance.

Keywords

Saline-alkali Land; Improvement Technology; Technical Safety.

1. Introduction

Saline-alkali soil refers to a kind of soil in which the salt content of soil exceeds that of normal cultivated soil, thus harming the normal growth of crops. The global saline-alkali land area is about 830 million hectares, and the total saline-alkali land area in China is 500 million mu, accounting for one eighth of the cultivated land area, which is mainly distributed in Northeast China, Northwest China and the Bohai Sea rim [1]. Salinization leads to soil structure destruction and nutrient imbalance, which seriously restricts crop yield. In recent years, through the strategy of "storing grain in the land and storing grain in technology", China has promoted technological innovation in the comprehensive treatment of saline-alkali land, and gradually formed a technical system with "changing the land to accommodate species" and "adapting species to the land" as the core, providing important support for food security and ecological restoration.

ISSN: 2710-0723

2. Origin and Characteristics of Soil Salinization

2.1. Genetic Analysis of Soil Salinization

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 [2]. Human factors mainly include excessive reclamation, unreasonable irrigation, etc., these activities will aggravate the soil salinization process.

2.2. Classification and Characteristics of Saline-Alkali Land

According to the salt composition, saline-alkali soil can be divided into chloride saline soil, sulfate saline soil and soda saline soil. The pH value of soda saline soil is often higher than 9.0, resulting in soil structure hardening and trace elements immobilized. According to the degree of salinization, the salt content of 0.1%-0.3% is light saline-alkali land, and more than 0.6% is heavy saline-alkali land, which needs systematic improvement measures to restore productivity. The formation of saline-alkali land is driven by many factors such as climate drought, high groundwater level, saline parent material and improper irrigation. For example, the salinity of groundwater in the Yellow River Delta rises to the surface along with the capillary water because of high salinity and shallow burial depth.

Saline-alkali land has high salinity, high alkali content, soil compaction and reduced biological activity. The contents of soluble salts such as sodium chloride and sodium sulfate in soil are significantly higher than the normal level, and the contents of alkaline substances such as sodium carbonate and magnesium hydroxide are higher, resulting in the rise of soil pH value. With the accumulation of salt and alkali, the soil gradually becomes rigid and hard, and the permeability becomes poor, which affects the growth and development of plant roots. At the same time, the growth of microorganisms and plants in saline-alkali soil was inhibited to different degrees, and the biological activity of soil was reduced overall.

2.3. Effects of Salinization on Agricultural Production

Studies have shown that soil salinization inhibits plant growth through osmotic stress, ion toxicity and soil structure deterioration. The increase of osmotic pressure of soil solution leads to countercurrent of plant root water and physiological drought. Na+ and Cl^- interfere with cell membrane function and enzyme activity and destroy photosynthesis. Salt condenses colloid, reduces porosity and microbial activity, and forms a plate layer [3]. Long-term salinization also led to the degradation of cultivated land. For example, the availability of nitrogen and phosphorus decreased by 40%-60% after the soil pH increased in the western Songnen Plain. High salt and alkali environment is toxic to crop growth, causing crops to be unable to absorb water and nutrients from the soil, and even causing crop death or extinction. Except for some specific plants with strong saline-alkali tolerance, normal crops are difficult to grow in saline-alkali land. In addition, salinization can also lead to a decrease in soil fertility, affecting crop yields and quality, and thus threatening food security.

3. Saline-alkali Land Improvement Technology and Safety Assessment

3.1. Engineering Improvement Technology

(1) Water conservancy improvement measures

ISSN: 2710-0723

Water conservancy improvement is one of the fundamental ways of saline-alkali land improvement, which mainly includes the construction of irrigation and drainage system (open ditch, hidden pipe, shaft), land leveling, sand mixing to reduce capacity and so on. By perfecting the irrigation and drainage system, the salt in the soil can be washed and removed, and the groundwater level can be regulated scientifically, so as to improve the water and salt status of the soil. However, there are some security risks in the implementation of water conservancy improvement measures. For example, open ditch drainage may cause soil erosion and water loss; For dark pipe drainage, pay attention to the installation and maintenance of the pipe to avoid the blockage or damage of the pipe. In addition, water conservancy improvement measures also need to invest a lot of manpower and material costs, and the improvement effect may be affected by geological conditions, soil types and other factors.

(2) Physical improvement measures

Physical improvement measures mainly include deep tillage, straw mulching, and guest soil transplantation. It has the advantages of low cost and obvious effect, but in the implementation process, it is also necessary to pay attention to the protection of soil structure, to avoid excessive tillage resulting in soil compaction and fertility decline. In addition, it is necessary to consider the source and quality of foreign soil in order to avoid introducing new pollution sources [4].

Deep tillage can improve soil permeability and water retention, and promote salt leaching and discharge. Straw mulching can reduce the evaporation of soil water and inhibit the rise of salt. Backfill technology mainly refers to the use of foreign soil or artificial soil backfill original soil, by increasing the organic matter in the soil and so on to improve the soil. This technology is mainly suitable for soil with high salinity and need quick repair in a short time. Choosing the way of backfilling of guest soil can protect the root soil of plant planting to the greatest extent and meet the growth needs. Through soil quality improvement, plants planted in saline-alkali land can become guest soil as soon as possible. By introducing foreign soil, the salt and alkali content of saline-alkali land can be reduced.

3.2. Chemical Improvement Technology

Chemical amendments are commonly used in saline-alkali land improvement, including gypsum, phosphonyls, lime, humic acid and so on. These amendments can promote the growth of crops by neutralizing the alkaline components in the soil, reducing the pH value of the soil, and improving the physical and chemical properties of the soil. However, the use of chemical amendments also has certain safety risks. On the one hand, excessive use of chemical amendments may have potential impacts on soil ecological environment, such as damaging soil microbial community structure and reducing soil fertility. On the other hand, some chemical amendments themselves may contain harmful substances such as heavy metals, which may cause harm to the environment and human health if not handled properly. Therefore, when using chemical amendments, it is necessary to strictly control the dosage and application method, and carry out adequate safety assessment.

In recent years, the application of fly ash and other industrial wastes in saline-alkali land improvement has been paid more and more attention. Fly ash has porous structure and ion exchange characteristics, and can be used as a "functional carrier" for soil structure improvement. By synergistic effect with organic fertilizer and salt-tolerant bacteria, a "physical-chemical-biological" multi-dimensional control system can be established to effectively improve the soil environment of saline-alkali land. However, the utilization of industrial wastes such as fly ash also requires attention to its potential environmental risks. On the one hand, fly ash may contain harmful substances such as heavy metals, which may cause pollution to soil and groundwater if not properly treated; On the other hand, the application amount and

ISSN: 2710-0723

method of fly ash also need to be reasonably adjusted according to the specific situation of saline-alkali land, in order to avoid adverse effects on crop growth.

3.3. Agronomic Measure

(1) Reasonable irrigation and drainage

Rational irrigation and drainage are one of the important agricultural measures in saline-alkali land improvement. By adopting water-saving irrigation technology such as drip irrigation and sprinkler irrigation, the evaporation and leakage loss of water can be reduced and the utilization efficiency of irrigation water can be improved. At the same time, combined with drainage measures can remove the salt in the soil in time to reduce the salt content of the soil. However, the implementation of rational irrigation and drainage measures also needs to consider soil type, crop type, climate conditions and other factors. For example, when using drip irrigation technology in clay soil, attention should be paid to prevent soil compaction and salt accumulation; In arid areas, it is necessary to strengthen the construction and maintenance of drainage facilities to ensure smooth drainage

(2) Increasing application of organic fertilizer and improving soil structure

Increasing the application of organic fertilizer can improve the physical and chemical properties of soil, improve the water and fertilizer retention ability of soil, and promote the growth of crops. At the same time, microorganisms and enzymes in organic fertilizers can also promote the decomposition and transformation of harmful substances in soil [5]. In addition, soil permeability and water retention can also be improved by improving soil structure, such as mixing sand and adding lime, which is conducive to salt leaching and discharge. However, increasing the application of organic fertilizer and improving the soil structure also need to pay attention to the problem of fertilizer amount and fertilizer method. Excessive fertilization may lead to excess soil fertility and nutrient loss; Unreasonable fertilization methods may affect the absorption and utilization efficiency of crops.

Humic acid and bio-organic fertilizer can reduce the pH and salt content of saline-alkali soil, and increase the soil organic matter content. Humic acid refers to a kind of brown or black macromolecular colloidal complex formed after complex changes of animal and plant residues. After soluble in water, it can form hydrophilic colloid. Under the action of plant roots, it condenses with calcium ions in soil to form an aggregate structure, reducing soil bulk density, increasing porosity, and thus increasing soil fertility. Studies have shown that the application of humic acid significantly reduces the soil salinity of 12.43% and the soil pH of 5.5%, and enhances the activity of microorganisms and enzymes in the soil, promoting plant growth [6]. Bioorganic fertilizer is a fertilizer fermented by natural substances such as feces, green plants and algae. When degraded in the soil, organic acids are released, thereby reducing the pH of the soil, and affecting the composition proportion of water-soluble salts in the soil by reducing the soil conductivity, so as to achieve the purpose of reducing soil salinity. It was found that bio-organic fertilizer could increase the content of organic matter in soil, increase the activities of nitrate reductase and urease, and then effectively reduce nitrogen loss and improve crop yield in saline-alkali land. However, different kinds of organic fertilizers had different effects on soil improvement.

(3) Planting saline-alkali tolerant crops and green fertilizers

Planting saline-tolerant crops and green fertilizers is one of the effective agricultural measures in saline-alkali land improvement. Saline-alkali tolerant crops have strong saline-alkali resistance and can grow normally on saline-alkali land and produce economic benefits. Green fertilizer can absorb the salt and nutrients in the soil through its roots and be converted into organic matter and released into the soil, thus improving the physical and chemical properties of the soil and improving the fertility of the soil [7]. However, the cultivation of saline-tolerant crops and green fertilizers also requires attention to the selection of crop varieties and planting

ISSN: 2710-0723

management. The adaptability of different crops to saline-alkali environment is different. Reasonable planting management can improve the yield and quality of crops.

3.4. Application of Smart Agriculture in Saline-alkali Land Improvement

(1) Application of digital farmland management system

The digital farmland management system can monitor the soil moisture, salt, nutrients and other parameters as well as the growth status of crops in real time by means of sensors and remote sensing technology, providing scientific basis for the accurate management of saline-alkali land. Through this system, the precision control of agricultural measures such as irrigation and fertilization can be realized, and the efficiency and benefit of agricultural production can be improved. However, the application of digital farmland management system also needs to consider the issue of data security and privacy protection [8]. In the process of data collection, transmission and storage, measures such as encryption and firewall should be taken to ensure data security. At the same time, it is also necessary to strengthen the protection of user privacy to avoid information leakage and other problems.

(2) Applications of drones and robots

Uav and robot also have wide application prospect in saline-alkali land improvement. Drones could be used for tasks such as soil sampling and crop monitoring; Robots can be used in agricultural operations such as sowing, fertilizing and weeding. The application of these technologies can improve the automation level and efficiency of agricultural production and reduce labor costs [9]. However, the application of drones and robots also requires attention to their safety and reliability issues. For example, the UAV needs to avoid collision with other aircraft or obstacles during flight; In the process of robot operation, it is necessary to ensure its stability and accuracy to avoid damage to crops.

4. Conclusion and Prospect

It is necessary to integrate engineering, biology, chemistry and agronomic technology to build a long-term management mechanism based on the principle of "applying measures according to local conditions" to improve the land productivity of saline-alkali cultivated land. In the future, interdisciplinary cooperation should be strengthened to promote the research and development of low-cost and green technologies, so as to achieve efficient utilization of saline-alkali land resources and sustainable agricultural development. Saline-alkali land improvement technology includes engineering improvement, chemical improvement, agricultural measures and smart agriculture, and each method has its unique advantages and scope of application. In the process of saline-alkali land improvement, the safety and effectiveness of the technology should be fully considered to avoid the harm to the environment and human health.

In the future, saline-alkali land improvement technology will pay more attention to interdisciplinary integration and technological innovation, the development of precision agriculture and smart agriculture, and the deepening of environmental protection and sustainable development concepts. With the continuous development of science and technology, interdisciplinary integration and technological innovation will become an important driving force to promote the development of saline-alkali land improvement technology. The development of precision agriculture and smart agriculture will improve the intelligent level and efficiency of saline-alkali land improvement and reduce labor costs. The concept of environmental protection and sustainable development will promote the saline-alkali land improvement technology to pay more attention to environmental protection and sustainability and reduce environmental pollution and damage; The support of government policies and the investment of funds will increase the research and development and promotion

ISSN: 2710-0723

of saline-alkali land improvement technology to promote the in-depth development of saline-alkali land improvement.

Acknowledgments

Research funding: This research was funded by the Technology Innovation Center for Land Engineering and Human Settlements, Shaanxi Land Engineering Construction Group Co., Ltd and Xi'an Jiaotong University (2024WHZ0235, 2024WHZ0233), Shaanxi Provincial Land Engineering Construction Group internal research project (DJNY-ZD-2023-4), Shaanxi Province Innovative Talent Promotion Program Young Science and Technology Rising Star Project (2023KJXX-123), Pre-research Project of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd (2024-NBYY-01).

References

[1] Bi C W, Che X B, Ma J C, et al. Determination of resistance and resistance level of phytophthora infectants to benalaxyl [J]. Journal of Southwest Agricultural University, 2022,24(4):307-310.

[2] Liu Q F, Liu Y X, Cao J F, et al. Effects of controlled release nitrogen fertilizer on yield and nitrogen use efficiency of cotton in fluvio-aquic soil of Bohai Sea Ring Area, Acta Agriculturae Zhejiangensis,2018,30(2):275-279.

[3] Lu J. Screening and Mechanism Analysis of Salt-alkali Tolerant Tomato Introgression Lines [D]. Shandong Agricultural University,2021.

[4] Geng Q M, Yan H H, Yang J Z, et al. Open trench and dark tube drainage effect on development of saline-alkali soil improvement evaluation [J]. Journal of soil bulletin, 2019, 50 (3):617-624.

[5] Zhang E Z, Chen J N, Huang Y, et al. Effect of different tube spacing and bio-organic fertilizer application on N2O emission in saline-alkali land [J]. Water saving irrigation,2025,(2):15-20+27.

[6] Wang Qi Z, Wang Yu, Sun Z M, et al. Improvement effect of humic acid application on saline-alkali soil [J]. Chinese Journal of Applied Ecology,2019,30(04):1227-1234.

[7] Chang W W, Liu J J, Wu Na, et al. Effects of water and nitrogen coupling on biomass yield, quality and water and fertilizer utilization of switchgrass in saline-alkali land [J]. China Soil and Fertilizer,2021,(1):53-62.

[8] Song K, Zhang G X, Li W H, et al. Research on the current situation, existing problems and countermeasures of innovation and promotion of improved varieties of suitable crops in saline-alkali land: A case study of Binzhou National Agricultural Science and Technology Park in Shandong Province [J]. China Rural Science and Technology,2023, (10):38-40.

[9] Li L L. Application research of UAV aerial survey in farmland land salinization monitoring [D]. North China University of Water Resources and Electric Power,2019.