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Salt Lake Agriculture and Its Development Strategy

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Abstract: China has many salt lakes; thus, the development of salt lake agriculture is of realistic and strategic significance in controlling desertification, ecological environment protection, economic growth in the western part of the country, and development of featured agriculture in semiarid and arid regions. With an increase in the global population, food and fresh water shortage will likely be aggravated; therefore, developing salt lake agriculture is essential for ensuring human food security and conducting strategic studies on salt lake agriculture becomes particularly urgent. This paper depicts recent achievements in salt lake agriculture and identifies problems hindering its development. Finally, suggestions are proposed on innovation-driven development of salt lake agriculture, including enrolling the discipline into national science and technology planning and zoning saline–alkali land in salt lake basins by their functions.
Keywords: salt lake agriculture; salt lake ecosystem; salt lake organisms

1 Introduction

Salt lake agriculture is a new, multidisciplinary research field involving aquaculture, agronomy, and husbandry that focuses on producing food and other crops in salt lake basins and water regimes [1]. Salt lake agriculture includes saline water aquaculture, and the growth of salt-tolerant plants in salt marshes around salt lakes. China has many salt lakes, and the development of salt lake agriculture is becoming increasingly featured in semiarid and arid regions. Recently, many lakes have been drying up owing to global climate change, and the desertification of lands in salt lake watersheds is worsening, thereby seriously affecting the environment and human health. With an increase in the global population, food and fresh water shortage will be aggravated; therefore, developing salt lake agriculture becomes essential in ensuring human food security. In a letter to Zheng Mianping, Qian Xueshen wrote, “Salt lake agriculture is a new future industry in the 21st century.” This paper depicts recent achievements in salt lake agriculture and identifies problems in salt lake agriculture development. Furthermore, it proposes suggestions for innovation-driven development of salt lake agriculture, including enrolling it into national science and technology planning and zoning saline–alkali land in salt lake basins by function.

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2 Strategic location and value of salt lake agriculture research

2.1 Ecological significance of salt lake development

Desertification in salt lake watersheds has become increasingly serious owing to the warmer and drier climate, lower lake water level, water salinization, and pasture degradation. For example, Anguli Nor, Chagan Nor, and Wulagaigaobi Nor, located near Beijing, rapidly dried up and their watersheds were heavily desertified. From 2001 to 2010, lakes in Inner Mongolia experienced significant shrinkage, with more than 2000 km^2 of salt and alkali watersheds acting as Beijing–Tianjin–Hebei sand source. Dry lake basins have gradually become salty and desert-like, thereby acting as sand or chemical material sources. Results have shown that the dried salt lakes provided 27% and 96.1% of the sand and salty sand, respectively, in the Beijing–Tianjin–Hebei region. Salt sand storms comprised high-density and small-diameter salt particles, such as sulfate, chloride, and heavy metal elements, including Mn, As, Rb, Pb, Sr, and Cr, which cause food, soil, water, and air pollutions as well as equipment corrosion. Consequently, ecology and natural environments have deteriorated [2]. Development of salt lake agriculture can help restore vitality in desert areas and green environments and reduce sand pollution. Therefore, salt agriculture has practical and strategic significance in desert control and ecological environment protection.

2.2 The development of salt lake has important significance for China food security

With an increase in the global population, food and fresh water shortage, especially high-quality protein, will likely worsen. Current agricultural production cannot fulfill the food and fresh water needs in some countries, particularly in the underdeveloped countries. Additionally, cultivated land and domestic supply of food have reduced in China. To this point, president Xi Jinping pointed out that “The home produced food should be mainly on our dining table.” Vast salt lakes, marshes, and ponds may become fine farmland by development of salt lake agriculture technology, thereby increasing the cultivated land area and food production. Therefore, developing salt lake agriculture is essential for ensuring human food security and cultivated land limited to 1.8×10^9 mu (1 mu = 666.67 m^2) in China.

2.3 Economic value of salt lake development

Salt lake systems contain abundant biological resources, and their economic value can be realized by developing salt lake agriculture. The well-known salt lake organisms include *Dunaliella salina*, *Artemia*, spirulina, rotifer, and halo-alkali bacteria. Since carotene content in *Dunaliella salina* can be up to 8%–10% (dry weight) and it is rich in glycerin (approximately 30%), protein (30%–40%), fatty acids, chlorophyll, and tetraene oil (dry weight), it has an important nutritional and health value and is very popular in the market [3,4]. *Artemia* has protein content of 57%–60% (dry weight), fat content of 18%, and contains a variety of amino acids, unsaturated fatty acids, and vitamins. Fish, shrimp, and crab growth require EPA fatty acids and minerals, which can be used as gonad development hormone and disease-resistant carrier, enabling early fish and shrimp maturation. Therefore, *Artemia* is a high-quality feed for Chinese shrimp, crab larvae, and high-grade fish [5]. The exploitation and utilization of these biological resources have important medical and nutritional values and broad economic prospects.

A variety of salt-tolerant plants, including 11 species of high-quality grasses, such as *Puccinellia Tenuiflora* and *Mordeum brevisubulatum*, in salt marshes around salt lakes are useful as feed for cattle and sheep and can also be used as energy plants. These plants are rich in nutrients, contain a variety of elements, and are naturally excellent pastures. Some of these plants can also be used as traditional Chinese herbs, thereby increasing their economic value. Furthermore, *Suaeda* specie has medical value since it contains conjugate linoleic acid. It can also be used as a tourist landscape plant because it causes salt lake beaches to present a large red landscape each autumn. The gradient ratio change of saline vegetation and unique habits of salt-resistant plants are the best choices for scientific research and eco-tourism in salt lake marshes [6].

2.4 Salt lake organisms have important scientific value

Salt and salt–alkali lakes are important but very fragile ecosystems. There are a large number of salt lake organisms with great scientific and practical significance. For example, many salt-tolerant economic plants have been cultivated on farmland. Additionally, some species of alkali bacteria have begun to be used in industrial production. Halophile purple membrane is an ideal photoelectric conversion material with a wide range of applications. The salt-resistant genes in salt-tolerant plants and halophilic and alkali bacteria can be used as special

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gene banks for cultivating new biological varieties resistant to salt or salt–alkali environments [7].

The development of salt lake agriculture can protect the biological resources of salt lakes, improve the deteriorating salt lake ecological environment, ensure food security, and increase the incomes of local farmers and herdsmen. Therefore, salt lake agricultural development possesses social, ecological, and economic benefits.

3 Achievements and knowledge on salt lake agriculture

3.1 Resources base for salt lake agriculture development

3.1.1 Rich salt lake resources

China has many salt lakes, with survey statistics showing 813 modern inland salt lakes larger than 1 km^2, accounting for 29.04% of the total salt lakes larger than 1 km^2. Total salt lake area is 4×10^4 km^2, accounting for approximately half of China's total lake area. Salt lakes in China have diverse water chemistry types [8] owing to the vast alkali soil and saline water in salt lakes in western China and the eastern coastal area, which account for an area and volume of approximately 1.5 billion mu and 50 billion m^3, respectively, making them potential land resources and salt mineral sources. These Quaternary salt lakes, which are mainly distributed in the Quaternary arid and semiarid climate zones globally, can be divided into two zones and two regions. Salt lakes in China can be divided into four salt lake areas, namely the Qinghai–Tibet Plateau Salt Lake Zone (I), the Northwest Salt Lake Zone (II), the Northeast Salt Lake Zone (or the North-Central Salt Lake Zone) (III), and the Eastern Scattered Salt Lake Zone (IV). Furthermore, these salt lake areas can be divided into subzones [9].

3.1.2 Salt lake organisms as agriculture resources

Salt lake is an extreme type of lake with special aquatic and terrestrial ecologies. Fresh water species cannot endure high salinity; therefore, they cannot live in such extremely salty environments. However, only a small amount of salt-resistant species can live and reproduce in such conditions. With an increase in the salinity of salt lakes, the richness of salt lake organisms decreases. Since predators are rare, salt-tolerant species can often adapt to high (super) salinity, and through more breeding in the right conditions, blooms can be extended to the entire salt lake or salt field. Salt lake ecosystems comprise two subsystems, namely a salt marsh belt and salt water. In salt marsh belts, salt-resistant organisms, such as Suaeda heteroptera, salt Chenopodiaceae, Sesbania, Chinese Tamarisk, and amorpha, are generally found, and can often be important pasture species. Besides alga and microorganisms, salt lake organisms also include higher plants and animals, such as Monocotyledon plants, Amphipoda, crustaceans, insects, flamingos, and tilapia.

3.1.3 Saline and alkali land resources as salt lake agriculture resources

China has many salt lakes that are distributed mainly in arid or semiarid areas of the western part of the country, such as Qinghai, Tibet, Xinjiang, Inner Mongolia, Heilongjiang, Jilin, Gansu, and Ningxia, which are underdeveloped economies. Hong Kong, Macao, and Taiwan are not considered currently. The total salt lake basin area is 5.236×10^6 km^2, covering 55.9% of China's total saline–alkali land area [10].

Herein, the Qaidam Basin is considered as an example. There are 51 lakes in the Qaidam Basin; all these lakes are saline except for the Lake of Keluke, which is a freshwater lake, and seven brackish water lakes. The mineralized degrees of the lake surface brine and intercrystalline brine of these salt lakes both exceed 50 g/L. The deposits of six larger playas in the Qaidam Basin rank first in global modern salt lake area. The Qaidam Basin features drought climate conditions; therefore, there are large areas of saline–alkali land resources. Data show that undeveloped and unutilized saline land accounts for approximately 11.7% of the Qaidam Basin's total land area. Furthermore, the proportion of salt–alkali soil areas in Qaidam Basin's agricultural land, grassland, and forest land is also considerably large; therefore, the salt–alkali land resources in this area are considerably rich. However, the detailed data are yet under statistics. Salt–alkali soil types in the Qaidam Basin mainly comprise desert salt soil, meadow salt soil, marsh salt soil, and lakeside salina. Since saline soil is not suitable for growing traditional crops, previous research based on the use of saline–alkali land at home and abroad has emphasized on the use of artificial soil engineering measures to adapt to "fresh water" crops. However, such soil improvement requires a large amount of fresh water to wash salt from the soil, and improved soil is prone to secondary salinization during farming. Resultantly, the saline–alkali resources in the Qaidam Basin are almost unutilized. A large area of saline land resources provides many land resources for developing salt lake agriculture [11,12].

3.2 Achievements in salt lake agriculture

3.2.1 Ecological management of the dried-up salt lake area of Inner Mongolia by salt organisms

In recent years, lakes have dried up and desertification of salt lake basins has seriously intensified with global climate change. For example, six lakes, including Angui Nor, Chagan Nor, Wulagaigaobi Nor and many others, near Beijing, rapidly dried up. Angui Nor, located in Zhangbei County, which is 200 kilometers away from Beijing, dried up in 2004. The lake basin then underwent saline desertification. Frequent sandstorms in Beijing during spring every year seriously affect human health and environment. Since 2008, an important breakthrough has been made in the treatment technology of pioneer plant *Suaeda* in the dried salt lake basin, with planting areas in Chagan Nor and Anguli Nor reaching 10 000 hectares, which attracted attention in China and abroad. Good ecological, social, and economic benefits have been achieved from these efforts.

3.2.2 The application of salt-resistant economic plants for Qinghai’s economic transformation

Results have shown that the use of salt-resistant economic plants played an important role in Qinghai’s economic transformation. (1) Although the salt-resistant plants in the Qarhan lake basin in Geermu city are relatively simple, they have considerable economic and ecological values. (2) The climate there becomes wet overall and water table in the basin area rises, providing a major water resource for ecological salt lake agriculture development. (3) Currently, black red wolfberries is an industry in the basin, with large-scale cultivation of red and black wolfberries taking place at Hedong Farm, Hexi Farm, Dagele Township, and Nuomuhong, among other places. The output value of wolfberry production has been considerable, proving the reasonable output value of ecological salt lake agriculture can fully meet local economic requirements. Additionally, other local plants, such as Nitratia, Apocynum, and reeds, have potentially high value. Other species adapted to the local environment can also be introduced to enhance salt lake agricultural output value.

4 The problems in salt lake agriculture development

(1) Salt lake agriculture is a new type of modern agricultural development with high-technology, high-input, high-efficiency, and high-risk characteristics. Therefore, there is an urgent need to investigate and resolve the lack in understanding, weak measures, and several other problems to strengthen salt lake agricultural development.

(2) Salt lake agriculture is a new research area involving many fields, departments, and disciplines; therefore, it must be improved theoretically and practically. Due to its relatively weak foundation, land and government policies, taxation, financial systems, talent, input, and other supporting factors are not perfect. Additionally, joint force development has not yet been undertaken, restricting the development of salt lake agriculture when coupled with a lack of commercial development and utilization.

(3) Currently, the development of salt lake mainly produces inorganic salts, and many salt lake ecological environments and biological resources have been destroyed. Only a few salt lakes still retain their original ecological and microbial resources; therefore, it is urgent to protect and identify the “black hole of Darwin’s Tree of Life” to rescue endangered biological genetic resources [13].

5 Suggestions on innovation-driven salt lake agriculture development

(1) The scientific and technological innovation in salt lake agriculture must be strengthened and salt lake agriculture must be included in China’s national science and technology plan. National, local, and enterprise-oriented specialized salt lake research and development institutions should be gradually set up by gathering multidisciplinary talent with an aim of gradually establishing a salt lake agriculture innovation system with Chinese characteristics.

(2) Salt lake basin climate, water resources, and soil and vegetation conditions were investigated and analyzed, and the functional area of the salt lake basin’s salt–alkali area was divided into three types, namely saline–alkali land that can be improved, naturally developed saline or saline–alkali land, and mixed development saline–alkali land. Saline water areas can be divided into areas with available salt-tolerant biological resources, e.g., salt algae, spirulina, and Artemia, and areas where such resources have not yet been found. Salt playas are classified based on microbial communities depending on the types of salt present. Multidisciplinary research is conducted to realize the scientific utilization of discipline development and resources and the improvement of agricultural potential by modern biology and technology.

(3) Five basic databases on soil, hydrology, meteorology, biological populations, and fine strains in the salt lake region should be established. Salt lake agricultural development should be conducted based on these five databases,

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covering biological, hydrological, and soil features in different regions. Major projects requiring priority support and those requiring key research and development include 1) water-saving soil desalting solutions based on hydrological technology, 2) construction of soil and hydrological databases around the western salt lake area, 3) interactions between salt lakes and surrounding groundwater, 4) improvement of soil fertility during agricultural soil transformation in areas around salt lakes, 5) freshwater treatment of mineral-based salt lakes, 6) rational allocation of water resources in and around salt lakes and construction of systematic water conservancy projects, and 7) research on the physiology, ecology, behavior, and pathology of salt-tolerant and halophilic species.

(4) Through the above research, to provide a solid scientific and technological basis for salt lake agriculture development in Qinghai, Xinjiang, Inner Mongolia, coastal, and other ecological areas, different salt lake agricultural demonstration bases should be set up at a state-level, followed by industrial integration of the salt lake agricultural base.

(5) The government should provide tax and other incentives to farmers and herdsmen to further develop salt lake agriculture. This will promote the innovation in the marketization and industrialization mechanisms of salt lake agriculture and raise the enthusiasm of enterprises, farmers, and herdsmen.

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