Approaches and Research Progresses of Marginal Land Productivity Expansion and Ecological Benefit Improvement in China

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Approaches and Research Progresses of Marginal Land Productivity Expansion and Ecological Benefit Improvement in China

Abstract
Marginal land refers to the land with low agricultural productivity and economic benefit and fragile ecology due to the prominent limitation of soil barrier, strong restriction of water and heat resources as well as harsh topographic conditions. In China, the existing marginal land is about 1.17 billion mu (15 mu is equal to 1 ha), which is the most important resource of strategic emergency to deal with the cultivated land gap of 700 million mu. Marginal land storage is a major strategy for national food security. It has become a new international research trend to increase the productivity and ecological functions of marginal land by modulating the interaction between plant and soil microbial. This includes breeding high stress-tolerant plants, screening and application of plant growth promotion rhizobacteria (PGPR) to promote plant growth on marginal land, and strengthening soil microbial functions to improve soil quality and health. In view of the marginal land productivity expansion and ecological benefit improvement, it is necessary to formulate the overall action plans based on the principles of ecological priority and green development. We should carry out the marginal land R & D project with the idea of "plant first, soil-improvement as the base, water security, microbial control, and the integration of plant-soil-microbial ecological system". (1) We should build a national database of marginal land and formulate the protection and management zoning plan. (2) We should develop four aspects of basic theory research namely, stress-tolerant plants breeding and its adaptive mechanism, efficient utilization of water and fertilize, soil obstacle factor reduction and biological networks induction/acclimatization, and the interaction between plant and microbial. (3) Focusing on coastal saline-alkali land in north and east China, soda alkali-saline land in northeast China, saline-alkali land in northwest inland, yellow spongy soils slope on the loess plateau, red soil and purple soil slope land in south hilly region, we should build different types of ecological farmland by integrating various technologies and theories. This will promote the protection and sustainable utilization of marginal land resources, and support the timely launch of the efficient use of contiguous marginal land to achieve the goal of increasing productivity by adding 700 million mu of medium-high grade arable land. This will be also helpful to ensure the implementation of the strategy of "storing grain in land and technology" and rural vitalization, and the construction of ecological civilization in China's ecologically fragile areas.

Keywords
marginal land, productivity improvement, conservation, sustainable exploitation, resource database, soil obstacle, resistant variety, functional microorganism, ecological farmland

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Approaches and Research Progresses of Marginal Land Productivity Expansion and Ecological Benefit Improvement in China

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Abstract: Marginal land refers to the land with low agricultural productivity, low economic benefit, and fragile ecology due to the limitation of soil barrier, strong restriction of water and heat resources as well as harsh topographic conditions. In China, the existing marginal land is about 1.17 billion mu (15 mu is equal to 1 hectare), which is the most important resource of strategic emergency to deal with the cultivated land gap of 700 million mu. Marginal land storage is a major strategy for national food security. It has become a new international research trend to increase the productivity and ecological functions of marginal land by modulating the interaction between plant and soil microorganisms. This includes breeding high-stress-tolerant plants, screening and application of plant growth-promoting rhizobacteria (PGPR) to promote plant growth on marginal land, and strengthening soil microbial functions to improve soil quality and health. For the expansion of marginal land productivity and improvement of ecological benefit, it is necessary to formulate the overall action plans based on the principles of ecological priority and green development. We should carry out the marginal land R&D project with the ideas of plant in priority, soil improvement as the base, water security, microbial control, and the integration of plant–soil–microorganism system.

1. We should build a national database of marginal land and formulate the zoning plan for protection and management.
2. We should develop basic research on the breeding and adaptation mechanism of stress-tolerant plants, efficient utilization of water and fertilizer, soil obstacle factor reduction and biological networks induction/acclimatization, and the interaction between plant and microorganisms.
3. Focusing on coastal saline-alkaline land in northern and eastern China, soda alkali-saline land in northeastern China, saline-alkaline land in northwestern China, sloping land with yellow spongy soil on the Loess Plateau, and sloping land with red soil and purple soil in southern hilly region, we should build different types of ecological farmland by integrating various technologies and theories. This will promote the protection and sustainable utilization of marginal land resources, and support the timely launch of the efficient use of contiguous marginal land to achieve the goal of increasing productivity by adding 700 million mu of medium-high grade arable land. This will be also helpful to ensure the food crop production based on farmland management and technological application, rural vitalization, and ecological civilization in China’s ecologically fragile areas. DOI: 10.16418/j.issn.1000-3045.20201228002-en

Keywords: marginal land; productivity improvement; ecological conservation; sustainable exploitation; resource database; soil obstacle; resistant variety; functional microorganism; ecological farmland

The per capita cultivated land resources in China are in shortage. In 2016, the total cultivated land area in China was 2.03 billion mu \(^\text{(1)}\), decreasing by 0.99 million mu every year, and the per capita cultivated land was only 1.3 mu \(^\text{(1)}\). In 2020, the total grain import of China was 142.621 million tons, of which soybean import accounted for 100.327 million tons, which means China relied on the productivity of 776 million mu of cultivated land abroad (calculated by the average soybean yield of 129.3 kg/mu in China, 2019). It is predicted that the self-sufficiency rates of three main grain crops (rice, wheat, and maize), soybean, and oil crops in China will reach 90%, 39%, and 60%, respectively, in 2030 \(^\text{(2)}\). Therefore, the future food security in China depends on the improvement in the productivity of existing cultivated land as well as the rational development and utilization of reserve cultivated land resources.

Marginal land is the most important resource of strategic emergency to guarantee national food security. It refers to the land with low agricultural productivity, low economic benefit, and fragile ecology due to the limitation of soil barrier, strong restriction of water and heat resources as well as harsh topographic conditions. In China, the existing marginal land is about 1.17 billion mu, including undeveloped reserve cultivated land (850 million mu) and existing low-grade cultivated land \(^\text{(2)}\) (320 million mu). The obstacle factors of
marginal land include climatic conditions (drought, cold), topographic conditions (high altitude, steep slope), soil conditions (shallow soil, high salinity, high acidity, low organic matter, poor nutrients), and resource conditions (lack of irrigation) [3]. The total area of five marginal land categories, i.e. saline-alkaline land, aeolian sandy soil, yellow spongy soils, red soil, and purple soil, is about 337.6 million mu, and they are mainly distributed in the hilly region in southern China (154.8 million mu), loess hilly region (34.7 million mu), northern sandy region (44.5 million mu), semi-arid and semi-humid region and arid region in northwestern China (85.76 million mu), and coastal saline-alkali region in the Yellow River Delta (17.9 million mu) (Figure 1 and Table 1). However, the existing technology to improve cultivated land quality and the existing stress-tolerant varieties cannot support the improvement and ecological utilization of marginal land. Coordinated efforts are in need for the improvement in the engineering system of marginal land and the technical system of crop breeding.

1 Significance of improving the productivity and ecological benefit of marginal land

1.1 Marginal land is an important supplemented land resource for food crop production based on farmland management and technological application

The stock cultivated land in China is mainly in intensive use. It is difficult to increase the productivity of the existing high-yield farmland that covers an area of 630 million mu. Marginal land can be an important resource of strategic emergency to deal with the cultivated land and grain gaps in China. The marginal land includes 320 million mu low-yield cultivated land with the standard grain output lower than 200 kg/mu. After transformation and breeding improvement, its grain output can be increased to 300 kg/mu, which is equivalent to an increase of 320 million tons in grain productivity; the 340 million mu reserve cultivated land that can be developed readily can provide the potential grain output of 68 million tons (calculated by the productivity of low-yield land) when utilized reasonably. This together will add about 100 million tons of grain output to make up for the food shortage in China. The marginal land can be reserved in the case of sufficient food production and utilized in the case of food shortage.
Despite the difficult management and high ecological risks in the development and utilization because of the strong soil obstacles (such as shallow soil, high salt content, strong acidity and alkalinity, severe wind and water erosion, and extreme drought), the marginal land in China has large potential for productivity improvement. The development of the theories and technologies to overcome the obstacles limiting marginal land and to expand its productivity benefit can support the transformation and productivity improvement of low-yield cultivated land, enable the food crop production based on technological application, and increase the self-sufficiency rate of agricultural products like grain and oil crops in China. Besides, it can establish clear development goals and mature technology models for the emergency use of reserve marginal land resources and support the food crop production based on farmland management.

1.2 Improving the productivity and ecological functions of marginal land is the key to developing regional characteristic agriculture, consolidating the achievements of targeted poverty alleviation, and supporting rural revitalization and ecological civilization

On one hand, marginal land is mainly distributed in poor and undeveloped areas where farmers have low per capita income and have difficulty in increasing their income. These are key areas delineated in the national plan of targeted poverty alleviation. Marginal land is suitable for the growing of characteristic crops including grain, oil crops, cotton, flax, fruits, vegetables, tea, tobacco, flowers, trees, Chinese medicinal materials, and forest products. In addition, it is suitable for the development of new planting and breeding models such as grassland husbandry. For example, planting sweet sorghum, Chinese wildrye, and alfalfa in northern China and high-quality forage grass in grassland mountains in southern China is a solution for the efficient utilization of marginal land with poor performance in crop production while excellent performance in forage production as well as a new eco-agriculture pattern that matches the environmental carrying capacity of land resources. The amelioration of marginal land will increase unit area productivity and economic benefits and further accelerate the development of the regional Internet + agricultural characteristic industrial chain, motivating farmers to start their businesses in their hometown and increasing their income. On the other hand, some marginal land in ecologically fragile hilly and arid areas is vulnerable to natural disasters such as water and soil erosion, drought, and wind damage, which results in low use efficiency of land resources. This is a shortcoming that restricts the green development of agriculture and the conservation of rural ecological environment in China. Developing the intensive development theory of marginal land can integrate resource saving with environmentally friendly and ecological conservation technology models. Moreover, the theory will facilitate the development of modern agriculture, inheritance of traditional culture, and the protection of green hills and clear waters in a coordinated manner in line with the natural rules by driving the development of ecological and leisure agriculture, contributing to rural revitalization.

2 Research progress and direction in the improvement and utilization of marginal land

2.1 The temporal and spatial evolution mechanism and the rapid reduction principle of key soil obstacles in marginal land have been studied and the biophysical technologies for efficient utilization of nutrients in marginal land have been integrated

2.1.1 A solid theoretical foundation has been laid in the evolution mechanism and control of soil quality

The Chinese Academy of Sciences (CAS) has long been dedicated to research on the theories and technologies for sustainable agricultural development and cultivated land conservation. CAS has conducted the research on Evolution Laws and Sustainable Exploitation of Soil Quality, Main Processes and Control Measures of Farmland Ecosystem in China, and Farmland Soil Fertility Improvement Mechanism and Directional Cultivation Measures in Major Grain Producing Areas with the support of National Basic Research Program of China (973 Program), carried out Soil Series Survey and compiled the Soil Series of China with the
support of Special Fund for Basic Research, and studied the Functions and Regulation of Soil–Microorganism System. Focusing on the red soil slope land in southern China, the sandy and moisture soil in the Huang-Huai-Hai Plain, the black soil in the Northeast Plain, and the coastal saline-alkaline land in eastern China, CAS has carried out systematic research on soil generation and classification, soil quality formation mechanism, soil fertility and biological functions of soil, efficient use of fertilizer, and plant nutrition principle and established a soil database [4]. The research findings reveal the quality evolution law of black soil, moisture soil, red soil, and paddy soil under different management measures [5]. After long-term positioning and networked research on the nutrient and water cycles of main farmlands in China, the techniques to increase the yield and efficiency of farmland with recycling of organic nutrients in different climatic zones have been formulated [6]. Besides, the research on the reduction of obstacle factors and the mechanism of soil fertility restoration in low-yield farmland as well as that on the improvement of soil fertility and biocontrol mechanism for the intensive use of farmland helps to establish the principle and technology of soil aggregate-organic matter-microorganism system [7]. The Technology and Its Application for Farmland Fertility Improvement and Large-scale Balanced Output Increase in Huang-Huai Region and the Characteristics and Construction and Application of Key Prevention and Control Technology of Farmland Acidification in Typical Red Soil Areas in China won the second prize of the National Award for Progress in Science and Technology in 2014 and 2018, respectively.

2.1.2 Fruitful achievements have been made in the distribution of microorganisms in farmland soil, the promotion of nutrient cycling mechanism, and biofertilization technology

On the basis of the composition of soil microorganisms in the main farmlands, forests, and grasslands in China, scientists have revealed the mechanisms of microorganisms in regulating carbon, nitrogen, and phosphorus cycles in soil, deciphered the mechanism of the aboveground-underground coordination and regulation in farmland soil, and developed the technical system for the research on soil microbial functions [8]. The composition of core functional microorganisms in typical dryland soil and paddy soil has been identified, and the “metabolic theory” of temperature promoting the succession of microorganisms has been confirmed [9]. On a regional scale, the body sizes of soil organisms (bacteria, fungi, protozoa, and nematodes) are negatively correlated with their abundance, diffusion rate, and niche width, and the community assembly of large soil organisms tends to be a deterministic process [10]. With the proposal of the biofertilization theory for infertile soil with macro-aggregates, it has been found that bacterial-feeding nematodes in red soil can enhance carbon sequestration, nitrogen promotion, and phosphorus regulation through selective predation of microorganisms [11]. Bacillus asahii with metabolic diversity becomes a “leader” that promotes the accumulation of organic matter and the phosphorus cycle because of the long-term application of manure in low-yield moisture soil [12]. Soybean root architecture and exogenous rhizobia can coordinate to regulate the network structure of rhizosphere microorganisms, and the inoculation of rhizobia can increase the abundance of most beneficial microorganisms in the rhizosphere [13].

2.1.3 Research direction: evolution mechanism and rapid reduction principle of key soil obstacles to marginal land

At present, we need to fully reveal the evolution mechanism and rapid reduction principle of key soil obstacles to marginal land on different temporal and spatial scales and uncover the environmental screening process, niche competition process, and random process of species during the assembly of soil biological community. It is essential to deeply study the mechanism of organic matter (including stable similar humic substances) with different activities to reorganize, optimize, and domesticate functional organisms in active soil areas (e.g., rhizosphere, aggregate), to develop soil microbial agents and supporting colonization measures, and to integrate biocatalyst controls for efficient utilization of nutrients in marginal land.

2.2 The stress tolerance of plants has been explored regarding plant genotypes and their interaction with microorganisms, and the technologies to match plant varieties with microbiome against stress in marginal land have been developed

2.2.1 A number of stress-tolerant crop varieties have been bred

The CAS founded the Strategic Priority Research Program which supported the Innovation System of Breeding by Molecular Modular Design. Driven by this project, the molecular modular dissection has been conducted for the high-yield, stable-yield, high-quality, and high-efficiency traits of rice, soybean, wheat, and maize. Scientists have identified GW7 and GW8 conferring grain width, GLW7/OsSPL13 conferring grain length and grain width, COLD1 conferring cold tolerance, Pigm conferring disease tolerance, and NITR1.1 conferring nitrogen efficient utilization in rice. Great achievements have been made in the synergistic improvement of high yield and high quality, the perception and resistance to low temperature, the broad-spectrum and long-lasting resistance to rice blast and balanced yield, the efficient use of nitrogen, and the heterosis mechanism with high-yield trait of rice [14]. The Molecular Mechanism and Variety Design for the High-yield and High-quality Rice won the first prize of the National Natural Science Award in 2017.
2.2.2 In-depth research has been conducted on the physiology and functional genomics of stress-tolerant plants

The response and adaptation mechanisms of rice, wheat, maize, sorghum, and Miscanthus to stresses such as saline-alkali, drought, acidity, and barren have been deciphered. In rice, osa-miR1848 affects the bio-synthesis of phytosterol and brassinolide by regulating the expression of the target gene OsCYP51G3, thereby mediating the growth and salt stress response [15]. Triarrhena lutarioriparia, a Chinese endemic Miscanthus species, can improve photosynthesis and water use efficiency by regulating the expression of genes in response to cold and drought [16] and deal with salt stress by altering the expression of the genes involved in stress response and photosynthesis [17]. The aluminum-tolerant and aluminum-intolerant rice varieties prefer ammonium nitrogen and nitrate nitrogen, respectively, and the location of the QTLs conferring aluminum tolerance and nitrogen utilization in the same region on the chromosome makes coordinated regulation feasible [18].

2.2.3 The assembly of plant microbial community has been discussed

The mechanism of microorganisms to assist crops in resisting saline-alkali, drought, and diseases has been studied, on the basis of which the assembly of plant microbial community has been discussed. The genome of bacteria in roots of the halophyte Suaeda salsa is rich in salt tolerance-related genes and aid in the salt tolerance of other plants [19]. Fatty acids are the main nutrients that plants provide for mycorrhizal fungi, and RAM2 and STR-STR2 proteins involved in the fatty acid transport can inhibit the pathogenic fungi from causing powdery mildew by reducing the synthesis of fatty acids in plants [20]. The mechanism of plant PRR immune receptors to recognize pathogenic microorganisms has been elaborated. The important pattern-recognition receptor CERK1 responds to the long-chain chitin, a component of fungal cell wall, through the dimerization of the extracellular LysM domain, triggers phosphorylation in the intracellular kinase domain, and activates the downstream defense response signaling pathway [21]. With the improved high-throughput technique, nearly 8,000 bacterial strains have been isolated from Arabidopsis thaliana, and the law of A. thaliana triterpenoids regulating root microbiome has been revealed [22]. The roots of indica rice are richer in microorganisms involved in the nitrogen cycle than those of japonica rice, and NRT1.1B can regulate microorganisms that transform nitrogen in the rice roots and thus alter the nitrogen utilization efficiency of indica and japonica rice in the field [23].

2.2.4 Research direction: the technology to match stress-tolerant varieties in marginal land with microbiomes

It is urgent to fully identify and apply salt-tolerant genes in the high salt-tolerant rice germplasm resources (such as ‘Haidao 86’ with a salt-tolerant rate of 0.5%–0.6%) and the tritigiria germplasm resources derived from distant cross between Elymus repens and Triticum aestivum, by GWAS, RNA-Seq, and metabolome (including plant hormone) analysis. Efforts should be made to uncover the mechanism of coordinated regulation between acid/aluminum tolerance and efficient nutrient utilization of rice, the coupling mechanism between the drought signal transmission and the growth of maize and wheat, and the mechanism for improving water use efficiency. We need to identify key microorganisms that promote stress tolerance in the roots of rice, wheat, and maize, explore the mechanism of plant genotype–microorganism interaction in regulating the structure of microbiome in the roots under different stresses, and establish plant microbiome assembly technology for adaptation to stresses in marginal land. Enhancing the adaptability and stress tolerance of plants will expand the production potential of marginal land.

2.3 The water–salt–nutrient coordinated transport mechanism of groundwater–soil–plant–atmosphere continuum (GSPAC) system upon multi-source irrigation in marginal saline-alkaline land has been studied, and the green and efficient model for marginal land development and utilization that can continuously control salt is in development

2.3.1 With the integration of the technologies for improving saline-alkaline land and cultivating stress-resistant crop varieties, the technology model to increase the yield and efficiency of Bohai Granary has been established and demonstrated

Shortage of fresh water resources and saline-alkaline soil restrict more than 40 million mu of medium-yield and low-yield fields and over 10 million mu of saline-alkali wasteland in the low plain area of Circum-Bohai-Sea Region. In order to increase the grain output by 5 million tons in 2020, the Ministry of Science and Technology of China and the CAS carried out the Technology Demonstration Project of Bohai Granary in 2013 in Hebei, Shandong, Liaoning, and Tianjin. The project has the core tasks of expanding the cultivated land area, increasing per unit yield, and guaranteeing water supply, with the goal of increasing grain and cotton yields, aiming to develop a modern and efficient grain industry for building the Bohai Granary [24].

This demonstration project constructed an optimum water irrigation system with an efficient multi-source water utilization technology for farmland [25]. With this technological achievement, the grain yield in the low plain area of the Circum-Bohai-Sea Region can be increased by 3.27 million tons under the targeted groundwater exploitation compression. The demonstration project bred a number of salt-tolerant and high-yield wheat and maize varieties. For example, the tritigiria varieties ‘Xiaoyan 81’ and ‘Xiaoyan
60° were suitable for the saline-alkaline land with the salinity below 0.2% and 0.3%, respectively, and the yield of ‘Xiaoyan 60’ was 7.9%–11.4% higher than that of the control variety ‘Jimai 32.’ The demonstration project approved salt-tolerant plant varieties such as ‘Haicheng 1,’ ‘Yanqi,’ and ‘Haiqi,’ developed a series of fertilizers and modifiers suitable for saline-alkaline land, and invented the winter freezing irrigation with saline water to improve the saline-alkaline land [26]. The project constructed the micro-regional regulation and salinity reduction cultivation technology and formed a rice planting system to fully support the improvement and soil fertility enhancement of the coastal saline-alkaline land. The Research and Demonstration of Integrated Technologies for Planting in the Saline-alkali Land in Coastal Plain won the first prize of the 2015 Award for Science and Technology Progress in Hebei Province. The Innovation and Application of Key Technology for Improving Soil and Increasing Grain Yield by Large-scale Cultivation of Rice in Soda Saline-alkali Land won the second prize of the National Award for Progress in Science and Technology in 2015.

On this basis, the circular agriculture model combining farming with animal husbandry has been developed, and the pattern of Internet + Bohai Granary initially took shape. These achievements laid the foundation for the development of modern agricultural service industry in the Circum-Bohai-Sea Region. The Technology Demonstration Project of Bohai Granary has fostered over 90 demonstration zones in more than 70 counties and cities in Hebei, Shandong, Liaoning, and Tianjin, covering 80.167 million mu farmland. It has cumulatively increased regional grain yield by 10.47 million tons, brought extra benefits of CNY 18.65 billion, and saved water of 4.35 billion cubic meters. Accordingly, a research institute–ministry–province coordinated facility mechanism and a demonstration and promotion mechanism guided by the government, supported by science and technology, led by enterprises and professional cooperatives, and participated by farmers have taken shape. This project drives the development of seed industry, processing industry, animal husbandry industry, and modern agricultural service industry.

2.3.2 Research direction: green and efficient development and utilization model of saline-alkaline land

Saline-alkali land is the main type of marginal land in China, and it is distributed from the humid coastal area in eastern China to the arid area in northwestern China. Different saline-alkaline lands experience complicated and varied water and saline movements, which requires an insight into the relationship of water and salt transport and the climatic conditions with crop growth in the GSPAC system upon multi-source irrigation in the saline-alkaline lands in different regions. It is necessary to study the physiological and ecological mechanisms of plants to adapt to the saline environment, deeply examine the coordinated migration and balance of water, salt, and nutrients in soil during the development and utilization process of different types of saline-alkaline land, develop large-scale and low-cost saline water irrigation modes in saline-alkaline land, and establish a green and efficient model for saline-alkaline land development and utilization that can continuously control salt.

3 Suggestions for improving productivity and ecological benefits of marginal land in China

3.1 Developing an action plan for marginal land productivity expansion and ecological benefit improvement in China based on the principles of ecological priority and green development

The plan for marginal land productivity expansion and ecological benefit improvement is a public welfare program that supports the food crop production strategy based on farmland management. Due to the wide distribution, the transformation of marginal land in China necessitates the solutions for a variety of problems, huge investment, and complex management. Therefore, the plan will involve the cooperation of Ministry of Agriculture and Rural Affairs, Ministry of Natural Resources, Ministry of Water Resources, and Ministry of Science and Technology. It is suggested that the Ministry of Natural Resources, Ministry of Agriculture and Rural Affairs, Ministry of Science and Technology, and National Administration for Rural Revitalization should jointly take the lead to develop an action plan for the productivity expansion and ecological benefit improvement of marginal land according to the national development strategy and the key regional development needs. The proposed plan should make full use of the ecological potential of the marginal land resources in China.

Since marginal land mainly exists in ecologically fragile hilly and arid areas, the productivity expansion and ecological benefit improvement should adhere to the principles of ecological priority and green development while taking into account economic rationality and maximization of comprehensive benefits, and be problem-oriented [27]. According to the integrated, systematic, and dynamic evolution law of regional mountains, rivers, forests, farmlands, lakes, and grasslands, comprehensive consideration should be given to complete geographic units and administrative divisions for the rational determination of the scope and scale of the projects. Scientific, legal, political, and economic means, as well as public participation, should be fully mobilized to coordinate the funds for the national strategic plan of rural revitalization, the construction of high-standard farmland, and the conservation of mountains, rivers, forests, farmlands, lakes, and grasslands. The financial investment should be used to guide social capital. Shareholding cooperative system, special subsidy, supporting funds, and loans with discount interest can be applied to the project. Engineering technology and biotechnology should be integrated for systematic management to promote the sustainable utilization of marginal land.
3.2 Establishing special projects to make theoretical and technological breakthroughs for marginal land productivity expansion and ecological benefit improvement

During the “13th Five-Year Plan” period, the key research and development projects focusing on marginal land were initiated, including the breeding of seven major crops, technological innovation for increasing grain yield and production efficiency, research and development of comprehensive technologies for reducing chemical uses and increasing production efficiency, restoration and protection of typical fragile ecosystems, efficient development and utilization of water resources, and intelligent agricultural machinery and equipment. However, the research on marginal land is dispersed and not systematic. Therefore, it is suggested to establish special projects to make theoretical and technological breakthroughs for marginal land productivity expansion and ecological benefit improvement in a systematic manner and to promote the integrated development of marginal land-related disciplines in China. The research on comprehensive management of marginal land involves multiple disciplines, such as farmland quality construction, ecological restoration, and molecular breeding of crops. The breakthroughs of theoretical and technological bottlenecks can be achieved through coordination of CAS, Chinese Academy of Agricultural Sciences, universities, and institutions of related departments.

The special projects for marginal land should focus on exploiting the production potential and ecological benefits of the extensive marginal land in China. Specifically, we need to delineate the zones for marginal land management, develop the technologies for coordinated utilization of water and fertilizers and for overcoming obstacles to marginal land, make breakthroughs in the plant root microbiome assembly, and construct the technology model for food crop production based on farmland management and technological application in the contiguous marginal land.

(1) Zoning for marginal land management. Focusing on different types of marginal land in China, we should conduct space–air–ground integrated surveys and networked positioning tests, and adopt molecular biological and modern analysis methods to understand the formation and distribution characteristics of different types of marginal land in China as well as the thresholds and degrees of obstacle factors. With the establishment of a resource database of marginal land, the development potential, ecological risks, and ecological benefits should be evaluated for the zoning of marginal land for protection and management.

(2) Technology for coordinated utilization of water and fertilizers and for overcoming obstacles in marginal land. We should breed stress-tolerant crop lines (varieties) to adapt to the obstacle factors in different types of marginal land, and reveal the morphological, physiological, biochemical, and molecular principles and mechanisms of their adaptation. Efforts should be made to illustrate the migration and transformation of water, salt, and nutrients in the GSPAC system and their utilization by crops in marginal land exposed to drought, saline-alkali, and erosion in ecologically fragile areas. On this basis, the technology for coordinated utilization of water and fertilizers and for overcoming obstacles in marginal land can be developed, and a coordinated mechanism of the utilization, protection, and productivity expansion of water, heat, wind, and ecological resources can be established.

(3) Root microbiome assembly technology. While breeding stress-tolerant varieties and overcoming soil obstacles, we should develop the theory regarding the microbiome assembly for soil fertilization and the technology for multifunctional biocontrol, reveal the mechanism of microorganism–plant–soil interaction, screen out the functional strains that adapt to vegetation succession and aid in stress tolerance of plants, and address key technical problems in root microbiome assembly.

(4) Utilization model of contiguous marginal land. Focusing on the Yellow River beach and coastal saline-alkaline land, the soda saline-alkaline land in northeastern China, the saline-alkaline land in northwestern China, the red soil slope land in southern China, the purple soil land in southwestern China, and the yellow spongy soils in northwestern China, we need to integrate the stress-tolerant varieties with the technologies for efficient use of water and heat resources, for reduction of soil obstacles, and for the soil fertilization with plant–microorganism–soil interaction. A technology model for the classification and utilization of marginal land can be built, which will demonstrate for the transformation of large-area marginal land, for the food crop production strategy based on farmland management, and for the rural revitalization. For example, in the Yellow River Delta, the principle of coastal saline-alkali sub-desalination under rain-fed conditions can be proposed on the basis of the water and salt transport mechanism in the GSPAC system, and the long-term salt control technology of cover in top–block in middle–drainage in bottom can be established for the coastal saline-alkaline land (Figure 2). Terrain microtransformation, saline water irrigation, and cultivation–breeding technologies should be integrated to build a coastal saline-alkali ecological farmland (Figure 3). The model of irrigating economic plants with saline water can be built for the slope area where wolfberry, honeysuckle, Sesuvium portulacastrum, Hibiscus hamabo, and Apocynum venetum can be introduced. A model of sprinkling irrigation with forage grass planting for salt reduction can be applied to the sloping land, and salt-tolerant plants like Chinese wildrye, Puccinellia distans, and Sesbania cannabina can receive the sprinkling irrigation diverted from canals. They can also be inoculated with soil fertilization microorganisms like rhizobia and efficient cellulose-degrading strains, together with the application of polyglutamic acid, to promote the plant growth and reduce the salinity. An integrated ecological pasture planting and
breeding model can be applied in watery areas where ornamental and purifying aquatic plants (such as duckweed, *Potamogeton crispus*, water lily, *Scirpus triqueter*, *Scirpus tabernaemontani*, and *Typha orientalis*), as well as fish (such as mandarin fish that adapts to a brackish water environment) can be introduced.

**Figure 2** Long-term salt control technology of cover in top–block in middle–drainage in bottom for coastal saline-alkaline land

**Figure 3** Ecological farm model in coastal saline-alkaline land integrating terrain microtransformation, saline water irrigation, cultivation, and breeding technology

4 Conclusion

The total marginal land in China is about 1.17 billion mu, including undeveloped reserve cultivated land (850 million mu) and existing low-grade cultivated land (320 million mu). Marginal land is the most important resource of strategic emergency to guarantee national food security. However, it is ecologically fragile and delivers low agricultural productivity and economic benefits due to the limitation of soil obstacles, water and heat resources, or topographic conditions. There are still bottlenecks to overcome if we seek to break through the limitation of water and soil resources and breed stress-tolerant varieties for marginal land. Focusing on the Yellow River beach and coastal saline-alkaline land, the soda saline-alkaline land in northeastern China, the saline-alkaline land in northwestern China, the red soil slope land in southern China, the purple soil land in southwestern China, and the yellow spongy soils in northeastern China, we should reveal the mechanism of crop–microorganism–soil interaction and develop functional enhancement technology. Moreover, efforts should be made to uncover the stress tolerance mechanism of crops, breed stress-tolerant germplasm resources, decipher the mechanism for efficient use and regulation of water and heat resources, elucidate the generation of soil obstacles, and develop the technology for soil fertilization. We also need to make theoretical and technological breakthroughs in marginal land productivity expansion and ecological benefit improvement in China in a systematic manner.

On a whole, marginal land productivity expansion and ecological benefit improvement play an important strategic role in implementing the Central Document No. 1, addressing the shortage and quality deviation of cultivated land, advancing rural revitalization, and promoting the construction of ecological civilization in new countryside. Developing the theory for marginal land productivity expansion and ecological benefit improvement and the technology model for classification and zoning of marginal land will lend strong theoretical, technological and demonstration support for the implementation of food crop production strategy based on farmland management and technological application. In addition, it will put into practice General Secretary Xi Jinping’s idea that Clear waters and green mountains are as good as mountains of gold and silver, contribute to the green production and lifestyle, and provide an important guarantee for consolidating national food security.

References


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