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Abstract

One of the burning questions of food security in current China is how to produce sufficient forage products and animal feeds. The limited arable land has to be devoted to cereal production, and exploring more terrestrial land is a prerequisite for the sustainable forage production and the development of grass-based livestock husbandry. Bohai rim is consist of coastal line of the North China Plain, which has a significant amount of medium-low yielding fields and unutilized saline-alkali land as well as intensive livestock production. In this study, a new concept of "Coastal Grass Belt", proposed by LI Zhensheng, an academician of Chinese Academy of Sciences (CAS), was introduced, which addresses how to develop grass/forage farming system according to the severity of salinity. This concept can not only improve soil quality but also provide sufficient forage for livestock. Meanwhile, the concept is also aligned with China's national strategies of storing grain in land and in agricultural technology to ensure the self-sufficiency of important agricultural products and the integration of the security of land and marine ecosystems. This paper provides a detailed description of the "Coastal Grass Belt" concept, elaborates its goals, key scientific issues and innovative modes, and analyzes the ecological environmental and economic-industrial benefits. Finally, the much-needed innovation platforms, agro-industry modes and policies for the development of "Coastal Grass Belt" are discussed.

Keywords

Coastal Grass Belt; Bohai rim; circular agriculture; grass-based livestock husbandry; ecology priority; green development

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"Coastal Grass Belt" as Paradigm for Grass-based Livestock Husbandry around Bohai Bay

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Abstract: One of the burning questions of food security in current China is how to produce sufficient forage products and animal feeds. The limited arable land has to be devoted to cereal production, and exploring more terrestrial land is a prerequisite for the sustainable forage production and the development of grass-based livestock husbandry. Bohai Rim consists of coastal line of the North China Plain, which has a large area of medium- and low-yielding fields and unutilized saline-alkali land as well as intensive livestock production. In this study, a new concept of Coastal Grass Belt, proposed by LI Zhensheng, an academician of Chinese Academy of Sciences (CAS), was introduced. It addresses how to develop grass/forage farming system according to the severity of salinity. This concept can not only improve soil quality but also provide sufficient forage for livestock. Meanwhile, the concept is aligned with China's food crop production strategy based on farmland management and technological application to ensure the self-sufficiency of important agricultural products and the integration of the security of land and marine ecosystems. This paper provides a detailed description of the concept of coastal grass belt, elaborates on its goals, key scientific issues and innovative modes, and analyzes the ecological, economic, and industrial benefits. Finally, the much-needed innovation platforms as well as agro-industry modes and policies for the development of coastal grass belt are discussed. **DOI:** 10.16418/j.issn.1000-3045.20210512001-en

Keywords: Coastal Grass Belt; Bohai Rim; circular agriculture; grass-based livestock husbandry; ecology priority; green development

1 New demand for green development in Bohai Rim region

The development of grass-based livestock husbandry is compatible with the natural resource endowment of the Bohai Rim. The Bohai Rim has a large area of medium- and low-yielding fields and unutilized saline-alkali land. The conventional agricultural development suffers from low output, lack of technical models, low efficiency, and excessive water consumption. It is urgent to overcome the existing problems in the use of saline-alkali land considering the unique resource endowment and environment characteristics in this area [1]. Planting salt-tolerant forage grass is a good way to ameliorate saline-alkali soil and improve soil productivity [2], which can facilitate the development of grass-based livestock husbandry in medium- and low-yielding fields around Bohai Rim.

The development of grass-based livestock husbandry meets the demand for green development around Bohai Rim. The serious soil salinization and the lack of crop varieties suitable for cultivation around Bohai Rim result in poor productivity [3]. Therefore, a new model for the use of saline-alkali land should come into shape. The construction of a coastal grass belt, integrating forage grass planting, grass product processing, and livestock breeding, is an effective solution to the bottleneck problem in the development of the saline-alkali land. Further, it can improve the water and soil utilization rates and agricultural output value, and cushion the conflicts between regional green development and conventional agricultural transformation.

The development of grass-based livestock husbandry meets the need of ecological protection around Bohai Rim. One of the core principles of grass-based livestock husbandry is prioritizing ecological conservation and boosting green development. Industrial development must be ecologically and environmentally friendly. Coastal area is the transition zone between land and sea [4,5] as well as between saline water and fresh water, featuring unique landscape. When it is to be developed and utilized, emphasis should be placed on the protection of resources and environment [6]. In view of the characteristics of the resources and environment in coastal area, ecological theories should be integrated with high technologies, such as biotechnology and ecological engi-

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neering technology, so that adaptive development, sophisticated development and modern industrial development of saline-alkali land can come true. This can systematically ensure high yield, high efficiency, safety, and ecological protection of agricultural production.

2 Objectives and key scientific issues of the green development of coastal grass belt around Bohai Rim

2.1 The concept of coastal grass belt: Proposing and implication

The concept of Coastal Grass Belt was put forward by Li Zhensheng, an academician of Chinese Academy of Sciences (CAS), throughout his efforts for improving and utilizing moderate to severe saline-alkali land in the coastal area over the past two decades. With the aim of ecological protection and the prerequisite of sound allocation of water and soil resources, the construction of coastal grass belt is geared to the need of building an entire industrial chain for the development of modern agriculture and animal husbandry in the coastal area. According to the distance from the offshore, the soil salinity, the dynamic changes of water and salt, the project of coastal grass belt aims to cultivate high-quality suitable forage grass and ecological grass, innovate water-saving and soil improvement technologies, develop modern cultivation and breeding systems, and create a new development mode for grass-based livestock husbandry on saline-alkali land.

2.2 Objectives of the construction and green development of coastal grass belt

(1) Ecological protection of coastal fragile zones coordinating with green development of grass-based livestock husbandry. Centered on the balance between the ecological benefits of the development of coastal grass belt and the non-point source pollution carrying capacity of the coastal fragile zone, the project explores the synergistic effect between ecological protection and efficient forage grass planting. The project takes into account the maintenance and restoration of ecologically fragile zones such as coastal tidal flat, intertidal zone, and heavily saline zone.

(2) Sound water and soil allocation coordinating with efficient forage grass planting. Considering the salt tolerance of forage grass, the salinization of arable land, and the cost of soil amelioration, the project strives to maximize benefits. The development in the Bohai Rim has to cope with the challenges of the protection of ecologically fragile zones and the allocation of natural resources with uneven distribution because of special geographical characteristics. Upon the limitation of water supply, the project uses exogenous carbon sources to improve soil quality and realizes efficient use of nutrients by forage grass through application of water-retaining fertilizers and microbial fertilizers.

(3) Transformation and upgrading of traditional grass-based livestock husbandry coordinating with the local development of science and technology services. The coastal grass belt construction project around Bohai Rim can be a paradigm for the grass-based livestock husbandry in northern China to transform from scattered family production to industrialized, standardized and modernized production. In the context of agricultural supply-side structural reform and the implementation of rural revitalization strategy, the green development of grass-based livestock husbandry has become an important part of China's agricultural development.

2.3 Key scientific issues in the construction and green development of Coastal Grass Belt

With the three major objectives of green development, sound resource allocation, and industrial upgrading in the fragile coastal zone, the construction and green development of coastal grass belt around Bohai Rim needs to tackle the following three key scientific problems:

(1) the coupling between the output of main non-point source pollutants from the forage grass planting-livestock breeding system and the ecosystem carrying capacity threshold of introduced materials in the coastal fragile zone;

(2) the economic benefit matching between planting of adaptive forage grass in local areas and the soil fertility improvement of salinized arable land, and the exploring, regulation and control of the law of water and fertilizer demand of forage grass;

(3) the optimization of forage grass planting structure oriented for animal nutrition enhancement, and the entire chain analysis of new energy-material flow modes such as grass-grain-cattle/cow and grass-pasture-industrial park.

3 New model for the construction of coastal grass belt

The distribution of natural resources is uneven in the coastal area. High-salt grass belt, medium-salt grass belt, low-salt grass belt can be built from offshore to inland. In the Yellow River Delta, salt-tolerant forage grass and new plant varieties are preferred. Water, fertilizer, and salt regulation coupling with planting in saline-alkali land, grass-grain rotation, grass product processing, feed formula, healthy farming of cow/mutton sheep, waste recycling and other technologies are integrated. A full set of technologies for optimizing the planting structure of forage grass and improving the yield and quality of circular agriculture in saline-alkali land are conducted. Finally, a grass-based livestock husbandry model with the characteristics of the Yellow River Delta is established (Figure 1). With this model, economic, ecological, and social benefits can be achieved all at once. This provides a comprehensive paradigm that can be referred to, replicated, and promoted for the rapid development of grass-based

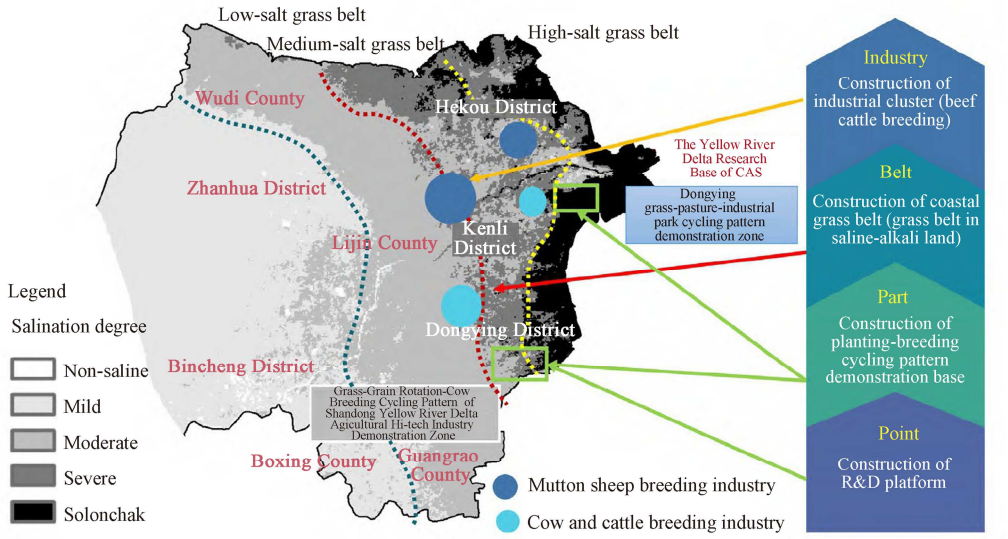

Figure 1 Coastal grass belt for both ecological conservation and industrial development of the Yellow River Delta

livestock husbandry in the Yellow River Delta and even in the agricultural areas of the whole China.

3.1 Demonstration of forage grass-grain rotation-cow farming cycling pattern in moderate and mild saline-alkali fields

The agricultural development in the Yellow River Delta has the problems of severe soil salinization, low and unstable crop yields, lack of salt-tolerant forage grass resources, shortage of high-quality roughage forage, and environmental pollution of manure. To solve these problems, Wuhan Botanical Garden of CAS takes the lead in integrating the key technologies of the collection and evaluation of local wild forage grass resources, selection of high-quality salt-tolerant varieties, optimization of forage grass-grain planting structure, improvement of soil fertility in medium- and low-yielding fields, high-yielding cultivation of forage grass, efficient use of water and fertilizer, green prevention and control of pests and diseases, mechanized seeding and harvesting, forage silage processing, and simulation and evaluation of nutritional requirements of dairy cows at different growth stages, efficient cow farming, recycling of wastes, and prevention and control of agricultural non-point source pollution. They constructed a base for the demonstration of large-scale forage grass-grain rotation-cow farming cycling pattern in moderate and mild saline-alkali fields.

3.2 Demonstration of "grass-pasture-industrial park" cycling model of high-yield and high-quality planting and breeding in saline-alkali land

In order to solve the problems of simple planting structure, disconnection between planting and breeding, extensive sheep breeding, and insufficient forage supply, the Institute of Geographic Sciences and Natural Resources Research of CAS takes the lead in carrying out the demonstration of salt-tolerant forage grass planting and grass product processing in high-salt saline-alkali fields. The team uses information technology to acquire data of sowing, fertilization, irrigation, harvesting, silage, and feeding. They introduce high-quality mutton sheep breeds and carry out simulation and evaluation of the nutritional requirements of and forage grass planting for mutton sheep at different growth stages. The team acquires the information of soil quality and safety and integrates the technologies for efficient breeding of mutton sheep and waste recycling. They build a demonstration base of "grass-pasture-industrial park" for high-yield and high-quality planting and breeding in saline-alkali land.

3.3 Research base construction and industrial mode of grass-based livestock husbandry in the Yellow River Delta

To achieve resource efficiency, ecological and environmental friendliness, and significant economic benefits, the Institute of Botany of CAS takes the lead in establishing the resource nursery for forage grass and characteristic germplasm resources under different salinity conditions and building a technical platform for resource collection, evaluation, and selection considering the land resources, water resources, and ecological conditions of the Yellow River Delta. They build the platforms for the evaluating the indicators of salt tolerance, water consumption, and fertility of major forage grass resources and rapid breeding platforms with indoor breeding accelerator. They plant moderately to heavy salt-tolerant grass species between forest and fruit rows to form a forest-grass intercropping model. Considering the resource endowment and the grass and livestock production structure in the Yellow River Delta, they evaluate the regional adaptability of "grass-grain-cattle/cow" and "grass-pasture-industrial park" modes. They optimize the spatial layout and set up a region-wide resource and

environment database for the Yellow River Delta. They propose an industrial layout map, an industrial development plan and supporting policies to step up the construction of coastal grass belt for the grass-based livestock husbandry in the Yellow River Delta.

4 Ecological benefits of coastal grass belt

4.1 Soil amelioration

The planting of forage grass can improve the physical and chemical properties of the soil. Different species of forage grass have varied effects of soil amelioration, and leguminous species perform better than graminaceous species. Compared with the aeolian sandy soil in the Yellow River floodplain, the soil in the forage grass-planting area has decreased bulk density and increased total porosity, capillary porosity, and non-capillary porosity. Leguminous forage grass can fix nitrogen directly while accumulating root residues in the soil, which can increase the organic matter in the soil. The nutrient content of soil increases gradually over time of forage grass planting and decreases with the deepening of the plough layer [7]. Salt-tolerant forage grass applied with soil amendments reduces the alkalinity, pH, and exchangeable Na^+ content in the 0–20 cm layer of alkaline soil. Meanwhile, it reduces the content ofHCO_3^-, CO_3^{2-}, K^+, and Na^+ [8].

4.2 Soil and water conservation

The rainy season in China concentrates in the peak growth period (i.e., June to September) of forage grass every year. Planting forage grass can reduce water loss and mitigate soil erosion. Soil bulk density and porosity are the basic physical properties of soil. Both of them directly affect the water storage and aeration of soil. Good physical properties of soil play a role in improving the antierodibility and antiscouribility of soil. Plants can control water loss and soil erosion. However, the soil and water conservation benefits of plants vary, depending on the growth and development of plants and the natural conditions such as rainfall and topography. When there is sufficient precipitation, the soil conservation capacity of forage grass is 300–800 times that of crops. Grassland can intercept 60%–90% of the precipitation [9]. Given the same precipitation, the amount of runoff from the land growing forage grass reduces by 95% compared with that of bare land.

4.3 Other ecological services

(1) Planting grass can regulate soil temperature and air temperature. In summer, it can lower the air temperature by 2 °C–6 °C and the soil temperature by 12 °C–22 °C compared with bare land. In winter, this measure increases air temperature by 4 °C–6 °C.

(2) Planting grass can increase air humidity by 10%–20% and decrease soil moisture evaporation by 60%–80% [10].

(3) Planting grass can purify the air. The grass can absorb carbon dioxide (CO_2) and dust in the air, and decompose toxic substances such as sulfur dioxide (SO_2), hydrochloric acid (HCl), carbon monoxide (CO), and hydrogen fluoride (HF) in the air and soil.

(4) Forage grass-crop rotation disrupts the attack cycle and parasitic relationship of insects and diseases, contributing to weed control and reduction of pesticide use [11]. It has potential application value in achieving the ecological prevention and control of pests.

5 Economic and industrial benefits of coastal grass belt

5.1 Productivity

The improvement of living standards and the change of consumption structure in the new era have contributed to the rapid development of livestock industry in China. The shortage of forage resources and high-quality green forage grass has become the major factors limiting the sustainable development of China's livestock industry. Studies have shown that forage grass can more effectively use natural resources such as light energy and land than grain crops. The planting pattern of rye in autumn and winter, silage maize in spring, and silage maize in summer can achieve three harvests of green forage within a year and increase the yield by 10.3%, light energy utilization efficiency by 35.0%, and water utilization efficiency by 16.7% over the conventional wheat-maize mode [12]. In addition, forage grass does not have strict requirement for soil. By planting forage grass in the areas that are not suitable for grain cultivation, farmers can obtain a certain amount of forage, improve soil, and prevent water loss and soil erosion, thus achieving great economic and ecological benefits.

Forage has complete nutrition and a high conversion rate. During the same season of growth, forage grass can obtain higher nutritional yield and protein content than crops and conventional feed. For example, the net energy for milk and crude protein content of alfalfa are 2.5 and 2.12 times, respectively, as high as those of soybean (including straw), and the lysine content of alfalfa is 4–5 times as high as that of maize [13,14]. In general, the protein content is 13%–15% in gramineous grass (dry weight) and 18%–24% in leguminous grass (dry weight). Moreover, the protein of forage can be more easily digested and absorbed by livestock. The calf feeding test showed that the protein utilization rate of alfalfa is 54.7%, while that of soybean is only 20.3%.

5.2 Development of grass industry

Planting grass in agricultural areas is a major step to improve the agricultural system and ensure food security. Developed countries have built a sound "food crop-economic crop-feed crop" agricultural industry structure. In these

Figure 2 Comparison of income items of forage and grain crops

developed countries, forage grass accounts for 1/3 of the planting industry, and the proportion of ruminants such as cattle/cow and sheep can reach up to 80% or more of the livestock industry, while this proportion is only about 25% in China [15]. The development of grass farming will trigger an arable land revolution in agriculture, which will provide momentum for improving agricultural systems. Moreover, it can exploit grassland resources, unleash huge food resource potential, set human food apart from livestock food, and thus ensure food security.

With the continuous improvement of China's economic level, Chinese residents' demand for meat, egg, and milk is increasing. Coupling the forage industry with the livestock industry will address this problem to a great extent. The livestock in the Yellow River Delta mainly consists of herbivorous animals such as cattle and sheep. The northern coastal area of the Delta is suitable for developing salt-tolerant forage crops such as alfalfa, sorghum hybrid sudangrass, and perennial ryegrass. The southern plain with better soil quality is suitable for developing silage maize and forage processing industry.

It is essential to increase the investment in science and technology to develop the grass-based livestock husbandry. At present, the output value per unit area of grassland in China is only equivalent to 1/20 of that in the United States, 1/10 of that in Australia, and 1/50 of that in the Netherlands. The contribution of science and technology in China's grass-based livestock husbandry is less than 30%, while this ratio exceeds 70% in developed countries [14,15]. Although forage production in China has been higher than that in the United States in recent years, the efficiency of forage production in China has been fluctuating. The amount of high-quality forage production and commercialization in China is still low. For example, the alfalfa production per hectare in China costs CNY 670.05, 1 117.95, 2 059.2, 563.7, and 4 156.95 for seeds, labor, fertilizer, water and electricity, and others, respectively, all of which are higher than the corresponding costs of alfalfa production in the United States. Meanwhile, the degree of mechanization of alfalfa production in China remains low. The mechanization expense of alfalfa production per hectare stays at CNY 2 384.55 in China while amounts to CNY 4 212.78 in the United States [16,17].

6 Measures for building the coastal grass belt around Bohai Rim to promote green development

6.1 Strengthening the building of technology innovation platform and capacity

(1) It is essential to access all kinds of innovative scientific and technological resources. Measures should be taken to attract talent teams from high-level domestic research institutions to the targeted research fields and bring their talent into play. CAS should collaborate with local governments, universities, research institutes, and enterprises to shape a science and technology innovation service platform for the development of modern agriculture and the construction of beautiful countryside around the Bohai Rim and in China's eastern coastal areas.

(2) The construction of the coastal grass belt around Bohai Rim and the green development of grass-based livestock husbandry constitute a systematic project, in which talents play a crucial role. Therefore, the talent structure should be improved. Specifically, equal emphasis should be placed between managerial talents and research talents, between technological developers and engineers, between model demonstrators and industrial managerial talents, between talent utilization and fostering. Thus, a talent reserve can be set up for the sustainable development of grass-based livestock husbandry in the coastal grass belt around Bohai Rim.

(3) The building of the coastal grass belt around Bohai Rim entails all kinds of funds to enhance the scope and the effect of project demonstration and promotion. ① Efforts should be made to actively undertake fund-supported projects such as the National Key R&D Program, provincial key R&D programs, and the Strategic Priority Research Program of

CAS. Support from various sectors at all levels for agricultural programs and for related industrial parks, platforms, and talents should be seeked for. ② It is suggested to encourage and guide local governments to increase the input for the counties to which major demonstration zones are affiliated. ③ Non-governmental capital from non-governmental enterprises and foundations should be attracted to participate in the building of coastal grass belt.

6.2 Upholding ecology priority and high-quality development

(1) The development and utilization of resources in medium- and low-yielding fields and unutilized saline-alkali land around Bohai Rim should prioritize ecological protection. ① The status quo of the ecological environment of the land that can be utilized in the construction zone should be evaluated to ascertain the cause and the fragility of the ecosystem. According to the different fragility degrees, different development modes and ecological compensation targets should then be proposed. ② A gross ecosystem product (GEP) accounting system should be developed. A GEP measurement method and indicator system tuning to the construction of the coastal grass belt around Bohai Rim should be established to measure the GEP brought by the development of grass-based livestock husbandry and comprehensively assess the development sustainability of the belt.

(2) The construction of the coastal grass belt around Bohai Rim should embark on a path of high-quality development to form a green and efficient development mode of grass-based livestock husbandry. While introducing or cultivating suitable forage species and herbivore resources, we should simultaneously guard against biological invasion. Efforts should be made to develop coastal germplasm resource banks and modern seed industry for grass-based livestock husbandry, and build an integrated seed-planting-breeding-processing-market-industrialization system. High value-added and high-quality green products should be developed. The information technology should be fully used to create new business models to propel the rapid development of modern agriculture and rural revitalization around Bohai Rim.

(3) On the basis of the natural endowment of the Bohai Rim and the distribution patterns of medium- and low-yielding fields and saline-alkali land, the construction project should uphold ecology priority and make good overall planning and zoning. It is recommended to optimize spatial layout, select high-caliber teams and establish demonstration bases in typical zones to ensure categorized and step-by-step implementation. The project should be laid out at multiple sites to form a protection network, and spatially differentiated technical models should be selected for integration and demonstration. In this way, it is expected that the coastal grass belt and a unique model of grass-based livestock husbandry can soon shape up.

6.3 Promoting the development of modern smart farming and animal husbandry

Big data and smart farming are inevitable trends in the future development of farming and animal husbandry. Modern smart farming and animal husbandry model is the accelerator for the development of traditional farming and animal husbandry, especially the coastal grass belt around Bohai Rim. Adopting Digital services for the whole process of modern farming and animal husbandry will save costs and realize high-quality development of grass-based livestock husbandry around Bohai Rim. However, the development and application of data acquisition and management application systems as well as smart farming application systems for the saline-alkali land remain seriously inadequate. In the wake of digital economy development, digital dividends are severely missing in the development of agriculture and animal husbandry in saline-alkali land.

Therefore, big data and smart farming technologies should be deeply integrated into the building of coastal grass belt around Bohai Rim to promote the high-quality development of grass-based livestock husbandry in the saline-alkali land. There is an urgent need to carry out solid and effective work in three aspects. ① Relevant databases should be built, including saline-alkali land background data (soil, water, climate, etc.), agricultural and livestock resources data (e.g., characteristic agricultural and livestock resources in saline-alkali land), data of scientific research activities (e.g., field positioning tests, indoor tests), production process management data (e.g., whole reproductive period monitoring of forage and livestock), equipment and facility management data (equipment and implementation monitoring, remote diagnosis, service scheduling, etc.), product and food security management data (origin environment, storage, processing, logistics information, etc.). ② A smart farming and animal husbandry application system should be built to serve precise zoning and categorized demonstration area construction, precise forage grass planting, precise livestock management, and system diagnosis and smart decision-making for grass-based livestock husbandry. ③ A smart farming and animal husbandry pattern of coastal grass belt should be built in the areas with suitable conditions. A smart farming and animal husbandry demonstration zone that is displayable, applicable, repeatable, and propagable should be set up.

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