Identification and Development of Suitable Agricultural Space in Cool Regions of Gansu Province (Postprint)

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Abstract

Cool climate constitutes an important resource supporting agricultural transformation and the cultivation of characteristic economies in northwestern mountainous regions. The comprehensive development of agriculture in cool climate zones can effectively enable Gansu Province to leverage its locational comparative advantages and advance high-quality agricultural development. Building upon a discussion of the strategic significance of cool-climate agricultural resources under the "Greater Food" concept, this study constructs a theoretical framework for the development of cool climate zones in Gansu Province. Employing natural indicator overlay analysis to identify the spatial orientation of advantageous cool-climate regions within the province, and utilizing the K-means clustering method, agricultural functional zoning is conducted for 169,249 grid cells at 1 km resolution within Gansu' s cool climate zones. The results indicate: (1) The cool climate zone in Gansu Province covers an area of approximately 1.69$×10^{5}$ km^2, accounting for about 41.97% of the province' s total land area, and is distributed across 12 cities (autonomous prefectures), 68 counties (districts), and 1,034 townships (towns). Cool-climate agriculture is dominated by animal husbandry and crop farming, with specialty forestry occupying a relatively small area. (2) The cool climate zones can be divided into seven agricultural development types: Northern Mountain Desert Alpine Animal Husbandry Zone, Qilian Mountain Arid-Cold Animal Husbandry Zone, Loess Plateau Arid-Cool Animal Husbandry Zone, Gannan Plateau Humid-Cold Animal Husbandry Zone, Hexi Corridor Warm-Cool Cropping Zone, Central Longshan Mountain Warm-Cool Agro-Pastoral Zone, and Southern Longshan Mountain Humid-Cold Agro-Forestry-Pastoral Zone, comprising four animal husbandry types, one crop farming type, and two mixed agro-pastoral types. (3) According to statistics at the 1 km grid cell scale, cool-climate animal husbandry, crop farming, and mixed agriculture account for 56.22%, 16.30%, and 27.49%, respectively; whereas at the administrative unit scale, the proportions of townships and counties capable of developing the three major agricultural types are relatively balanced, with approximately 30% each.

Full Text

Identification and Development of Suitable Agricultural Space in Cold and Cool Regions of Gansu Province

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Abstract

Cold and cool climates represent vital resources supporting agricultural transformation and the cultivation of characteristic economies in northwestern China' s mountainous regions. The comprehensive development of agriculture in cold and cool zones can effectively promote Gansu Province's comparative locational advantages and advance high-quality agricultural development. This study constructs a theoretical framework for developing cold and cool zones in Gansu Province based on the strategic significance of cold and cool agricultural resources against the backdrop of the holistic "Greater Food" approach. Using natural indicator overlay analysis, we identify the spatial orientation of advantageous cold and cool climate regions within the province. K-means clustering methods are then applied to classify agricultural functional types across 1 km precision grid units within Gansu's cold and cool zones. The results indicate: (1) Gansu' s cold and cool zones cover approximately 1.69×10^{5} km^2, accounting for 41.97% of the province' s total land area, distributed across 12 cities (autonomous prefectures), 68 counties (districts), and 1034 townships. Cold and cool agriculture in these regions focuses primarily on animal husbandry and crop cultivation, with a smaller area dedicated to characteristic forestry. (2) The cold and cool zones can be divided into seven agricultural development types: the Beishan Desert Alpine Pastoral Area, Qilian Mountain Dry-Cold Pastoral Area, Loess Plateau Dry-Cool Pastoral Area, Gannan Plateau Wet-Cold Pastoral Area, Hexi Corridor Warm-Cool Cultivation Area, Longzhong Mountain Warm-Cool Agro-Pastoral Area, and Longnan Mountain Wet-Cold Agro-Forestry-Pastoral Area. (3) Based on 1 km grid unit statistics, cold and cool pastoral, cultivation, and mixed agriculture account for 56.22%, 27.49%, and 16.30% respectively. At the administrative unit scale, the proportions of townships and districts capable of developing these three major agricultural types are relatively balanced, each representing approximately 30%.

Keywords: cold and cool area; cold and cool type agriculture; agricultural type; Greater Food approach; Gansu Province

1. Introduction

"Food is the paramount concern of the people," and food security represents a fundamental national priority. Against the backdrop of volatile international grain trade and scarce domestic ecological resources, China' s domestic agricultural market has long suffered from structural problems of surplus staple grains alongside shortages of quality agricultural products. In recent years, President Xi Jinping has consistently emphasized the "Greater Food" approach as a guide to promote high-quality agricultural development in the new era. This approach requires improving food security capabilities on one hand, while achieving diversification in food supply types. On the other hand, it necessitates breaking through resource constraints to diversify food supply sources. How to tap into the potential of diverse food production based on China' s resource endowments and ensure food security and high-quality agricultural development under the new era' s "Greater Food" perspective represents a noteworthy issue.

A historical value judgment exists in economic development: during the agricultural civilization period, fertile plains were the preferred production sites; during the industrial civilization stage, geographical advantages along rivers and coastlines gradually emerged; and entering the new era of ecological civilization, the precious value of mountainous areas has become increasingly prominent. The vertical terrain determines climate variability, environmental diversity brings resource pluralism, and the cold, cool low-temperature environment of mountainous areas enables more adequate accumulation of dry matter such as proteins and soluble sugars in crops. Additionally, well-developed root systems result in higher content of aromatic substances, alkaloids, minerals, and other nutrients, making the nutritional value of agricultural and livestock products far superior to that of plain regions. Therefore, the "granary" potential of forest and grassland in cold and cool mountainous areas is substantial, and their sustainable development and utilization can provide guarantees for improving agricultural quality and efficiency, representing a new direction for promoting high-quality development of characteristic mountainous agriculture.

Currently, relevant terminology surrounding "cold and cool zones" can be divided into three categories: cold and cool climate, cold and cool ecology, and cold and cool economy. Influenced by traditional agricultural production concepts, low temperatures, insufficient heat, and frequent disastrous weather resulting from high altitude and latitude have long been regarded as limiting factors for agricultural development. Consequently, research still predominantly focuses on grain production pathways and potential in plain agricultural regions, with few explorations of new food production methods based on non-cultivated land (forest and grassland) in vast mountainous areas. There remains a lack of research on agricultural development types and directions in key cold and cool resource sample areas based on natural endowments, as well as a shortage of beneficial practical exploration and experience in leveraging China' s mountainous agricultural depth by maximizing strengths and circumventing weaknesses to break through development bottlenecks. As a crucial region in northwest China, Gansu Province bears important missions for national food security, ecological security, and border security, making its exploration of mountainous characteristic agriculture extremely significant for the entire country.

In summary, this study follows the logical 主线 of theoretical analysis → cold and cool zone delineation → agricultural function type zoning. First, we discuss the transformation logic of China' s high-quality agricultural development under the "Greater Food" perspective, and based on an assessment of Gansu Province' s agricultural development status and challenges, theoretically address why cold and cool agriculture needs to develop. Second, through overlay analysis of eight natural indicators, we identify the spatial scope of cold and cool zones and employ K-means clustering to conduct agricultural type zoning at the 1 km grid unit scale, clarifying regional specialization directions at a finer scale. This aims to plan rural revitalization paths based on local cold and cool resource characteristics, gradually aligning agricultural production structure adjustments with the needs of ensuring greater food security, and promoting agricultural efficiency, farmer income growth, and rural development.

1.1 The Transformation Logic of High-Quality Agricultural Development from the "Greater Food" Perspective

In the 1980s, under the "grain as the key link" agricultural production policy, China prioritized staple grain security as its primary goal, continuously increasing agricultural production income. After solving the problem of "having enough to eat," President Xi Jinping proposed the "Greater Food" concept, breaking through the traditional constraints of "grain as the key link" and requiring gradual changes in the proportion of "staple" versus "non-staple" foods to improve people' s dietary structure. Since the 18th CPC National Congress, food security has begun emphasizing not only quantity but also common security in terms of quantity, quality, and nutrition. The 2022 Central No. 1 Document first included "establishing a Greater Food approach," and in 2023, "establishing a Greater Food approach" was incorporated into the chapter on "stable production and supply of grain and important agricultural products," requiring attention to meat, egg, and milk consumption and focusing on improving people' s nutritional structure.

Examining policy orientations across different agricultural development stages, China' s agricultural production has undergone conceptual shifts from traditional "grain as the key link" to "Greater Food" and then to "Greater Food approach." The concept of agricultural production has continuously expanded from initial quantitative security to quality and nutritional security, evolving from focusing only on staple grain security to addressing food structure and nutritional security. Agricultural development goals have progressively shifted from ensuring grain production increases and self-sufficiency rates to a demand orientation that simultaneously concerns food quantity and quality, and ultimately toward a nutrition orientation that ensures food security and improves national health. This transformation reflects the discourse shift at the entrance of "quantity → quality" in the new era.

1.2 Theoretical Framework Construction for Cold and Cool Zone Development in Gansu Province

Gansu Province' s cold and cool climate resources exceed 75.5% of its area, significantly superior to eastern and central regions of China. However, due to long-term unreasonable land use structures and exploitative development in the past, not only has grain production failed to increase, but ecological system imbalances have also occurred, urgently requiring new pathways for transforming traditional agriculture to modern agriculture. Against the macro background of national ecological civilization construction, the cold and cool economy plays an important mission in supporting economic transformation and cultivating characteristic economies across China' s vast territory, representing the main battlefield for agricultural development under the historic shift in focus of "agriculture, rural areas, and farmers" work in the new era.

In terms of regional orientation, cold and cool agriculture development primarily targets vast high-altitude and high-latitude mountainous areas. Research shows that agricultural products from cold and cool ecological environments have superior flavor, higher quality, and greater safety compared to plain regions. The long-term cold and cool low-temperature environment inhibits microbial and pest reproduction. Combined with vast, sparsely populated areas far from urban centers with minimal urbanization and industrial pollution, agricultural products possess natural green safety advantages. Based on the distinct characteristics of mountainous cold and cool climates differing from traditional plain regions with concurrent rainfall and heat, although agricultural yields are not as high as plain cultivated land, they possess absolute competitive advantages in quality.

In terms of type and method orientation, cold and cool agriculture is a green, ecological, and efficient agriculture focusing on forestry and animal husbandry with cultivation as a supplement. By guiding fruit and forestry industries uphill, it allows development of livestock products adapted to local climate productivity and land conditions beyond grain crops, without destroying the cultivated layer. This promotes adjustment and optimization of agricultural planting and breeding structures to align with upgraded consumption structures and dietary patterns, providing effective guarantees for supporting a diversified food supply system. Additionally, by coordinating previous contradictions between grain and cash crops, grain and feed, and grain and oil, it can not only prevent the "non-grainization" and even "non-agriculturalization" of cultivated land but also alleviate pressure on cultivated land resource protection and local water-land carrying capacity. This not only helps leverage regional resource advantages but also prevents farmland abandonment when farmers cannot plant cash crops or when grain crops yield low profits.

In terms of goal orientation, cold and cool zone development represents an agricultural development path for Gansu Province that leverages comparative advantages by maximizing strengths and circumventing weaknesses while enhancing competitive advantages through survival of the fittest. By establishing a cold and cool agricultural production system adapted to local climate production potential and land conditions, Gansu' s extensive mountainous cold, dry climate disadvantage can be transformed into a resource advantage for characteristic agricultural production, fully aligning with the national "store grain in land" strategy of "obtaining grain from mountains, forests, lakes, and seas." This drives innovation in the national food supply system and regional specialization of agriculture, solidifying the foundation of grain production while providing possibilities for crop multi-suitability and regional specialization. It represents a beneficial attempt to tap into the depth of mountainous agriculture based on China' s 本土 resources.

In summary, at the discourse transition entrance of "quantity → quality" in the new era, this study constructs a logical framework for developing cold and cool agricultural resources that takes high-altitude cold and cool climate advantage zones as the regional orientation, characteristic forestry and animal husbandry as the main development types, high-quality agricultural product production as the method orientation, and promotion of high-quality mountainous agricultural development as the goal orientation.

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2. Materials and Methods

2.1 Study Area Overview

Gansu Province features the locational characteristics of "connecting seven regions" and "bordering Tibet and Xinjiang," serving as an important province on the Silk Road Economic Belt and the only western Chinese province with 区位优势 connecting east and west while expanding north and south. Mountainous plateaus account for 75.5% of the province' s area, with solar radiation resources more than 10~16% higher than eastern regions at the same latitude. The complex natural environment and light-heat conditions have nurtured abundant famous, special, and rare resources, making it a typical region suitable for developing cold and cool characteristic agriculture. Based on Gansu Province' s "14th Five-Year Plan," this study divides the province into the Hexi Region (Jiayuguan, Jiuquan, Zhangye, Jinchang, Wuwei), Longzhong Region (Lanzhou, Baiyin, Dingxi, Linxia), and Longdongnan Region (Qingyang, Pingliang, Tianshui, Longnan, Gannan).

2.2 Geographic Overlay Analysis

Overlay analysis is a method that divides regional units through spatial superposition of two or more sets of factor layers in the same area. Natural environmental combinations within a region determine agricultural land use patterns and intensity, variety selection and layout, serving as the fundamental basis for type classification according to regional characteristics. Referencing relevant research, this study constructed an evaluation model for agricultural development type zoning in Gansu' s cold and cool zones from seven dimensions: topography, water resources, wind resources, light-heat resources, vegetation resources, land resources, and farmland resources, following comprehensiveness, scientificity, and availability principles to determine 8 indicators (Table 1). Using 1 km grid units as the foundation, this study conducted agricultural function-oriented regional type classification for Gansu Province to identify suitable agricultural areas and determine agricultural development types and layout optimization schemes.

The overlay analysis selected eight indicators: elevation, slope, annual average temperature, $ $10°C accumulated temperature, annual average sunshine hours, monthly average diurnal temperature difference, bare land proportion, and normalized difference vegetation index (NDVI). Data were processed according to specific indicator ranges using ArcGIS 10.8 software to create 1 km grid units. By overlaying raster factor layers, the geographic spatial scope of Gansu' s cold and cool zones was identified.

2.3 Evaluation Model Construction

2.3.1 Indicator Selection and Explanation The productivity level of cold and cool agricultural resources is closely related to natural environmental conditions. This study selected eight indicators from the conceptual dimensions of cold and cool environment: elevation, slope, bare land proportion, annual average temperature, monthly average temperature, monthly average diurnal temperature difference, annual average sunshine hours, and $ $10°C accumulated temperature to identify a total of 169,249 grid units in Gansu' s cold and cool zones. After linking with eight natural indicators to create unified vector units, abnormal values, duplicate values, and missing values were removed.

2.3.2 Determination of Indicator Weights Since data for various indicators used to discriminate and classify regional cold and cool agricultural development types have dimensional differences, original data require range standardization processing to make processed indicator values fall within the [0, 1] range. As this study aims to divide grid units within the research area into multiple categories based on internal similarity (maximizing intra-class similarity and minimizing inter-class similarity), evaluation indicators have no distinction between positive and negative indicators, and all are standardized as positive indicators. The calculation formula is:

$$X_{ij} = \frac{X_{ij} - \min X_j}{\max X_j - \min X_j}$$

where X_{ij} is the standardized processing result of the jth indicator for the ith grid unit in Gansu' s agricultural type classification index system; $\max X_j$ and $\min X_j$ are the maximum and minimum values of all original data for the jth indicator in the index system.

To avoid bias from subjective factors, this study employs the entropy method based on the established evaluation system to obtain indicator weights according to the information volume provided by each indicator. The calculation formulas are as follows:

$$H_j = -k \sum_{i=1}^{n} Y_{ij} \times \ln Y_{ij}$$

$$Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}$$

$$W_j = \frac{1 - H_j}{\sum_{j=1}^{m} (1 - H_j)}$$

where H_j is the entropy value of the jth indicator after standardization; $k = 1/\ln n$; m is the total number of indicators; n is the number of grid units (in this study, $n = 169,249$); Y_{ij} is the proportion of the jth indicator for the ith grid unit; X_{ij} is the standardized value of the jth indicator for the ith grid unit; and W_j is the weight of the jth indicator. Based on the entropy method' s principle of highlighting local differences, Gansu' s regional differences in light-heat resources are relatively small, resulting in smaller weights, while land resource spatial distribution differences are larger with greater utility value, thus receiving larger weights, consistent with previous research.

2.4 K-means Clustering Analysis

K-means clustering analysis is an unsupervised learning clustering algorithm based on Euclidean distance. The classification results satisfy the principle of minimizing intra-class differences and maximizing inter-class differences, representing an effective method for dividing datasets into several groups to explore spatial distribution patterns and typical characteristic patterns. The initial data for clustering analysis are obtained by multiplying the standardized values by their corresponding weights. The specific clustering process involves: (1) dividing 169,249 grid units into k classes and randomly selecting k grid units as initial class centers; (2) assigning remaining grid units to the nearest class based on the nearest distance rule to obtain k type clusters C_k, and taking the mean of all grid units in each cluster as the new class center; (3) reassigning grid units to the nearest class center and iteratively repeating this process until class centers no longer change, generating the final type grouping.

The objective function is:

$$J(C) = \sum_{k=1}^{K} \sum_{x_i \in C_k} w_i \cdot d(x_i, C(x_i))^2$$

where $J(C)$ is the sum of squared distances from grid units in each type cluster to their class center; w is the element weight; d is Euclidean distance; x_i is the ith grid unit; and $C(x_i)$ is the center of class C. To determine the optimal parameter value for classification k, the Calinski-Harabasz pseudo-F statistic is used to assess between-group differences and within-group similarity for different grouping methods, judging model fit. After multiple trials, a k value of 7 yields the highest F-statistic, indicating the most credible classification results.

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3. Results

3.1 Identification of Cold and Cool Zone Geographic Range

3.1.1 Geographic Scope Identification Elevation variation is the fundamental element of mountainous agro-forestry-pastoral climate zones. This study selected mid-altitude regions of 1000-3500 m as the research object. Regarding slope, since this study conducts spatial type classification for agricultural production in cold and cool zones, areas with slopes above 25° were excluded as they cannot be used for agricultural reclamation and planting. By consulting requirements for temperature conditions in livestock grazing, temperatures $ $25°C are unfavorable for livestock growth, establishing the upper limit of monthly average temperature. Total heat indicators generally use accumulated temperature for climate zone classification. In Gansu, regions with $ $10°C accumulated temperature below 1300°C have unstable agricultural output, so areas with 1300-3500°C $ $10°C accumulated temperature were selected. Additionally, regions with annual average sunshine hours >2000 h, monthly average diurnal temperature difference >10°C, and annual average temperature <10°C possess prominent cold and cool climate characteristics, suitable for both cold-environment crops and meeting agricultural climate conditions required for "stable production."

Due to Gansu' s harsh climate conditions of drought, severe cold, and strong winds, the province has 71,464 km^2 of bare land not covered by vegetation. These areas have extreme environmental conditions and currently belong to undeveloped land, thus being excluded from cold and cool zone identification. By unifying the spatial scale of eight indicators into 1 km grid units and using overlay analysis, cold and cool zones were obtained (Figure 4). After eliminating abnormal values and no-data grids, 169,249 grid units were obtained.

3.1.3 Regional Proportion of Cold and Cool Zones To identify cold and cool advantage areas at administrative unit scales, cold and cool raster regions were intersected with administrative boundaries. Cities (autonomous prefectures), counties (districts), and townships with cold and cool zone area proportions exceeding 30% were selected. Results show (Figure 6) that Gansu Province has 12 cities (autonomous prefectures), 68 counties (districts), and 634 townships suitable for developing cold and cool agriculture.

At the city scale, representative areas include Baiyin, Lanzhou, Dingxi, Jinchang, Linxia, and Qingyang. At the county scale, 88.2% of counties (districts) have cold and cool advantages, with 57.4% having cold and cool area proportions exceeding half. Among these, Linxia County, Gaolan County, Anding District, and Baiyin District are all high-proportion areas. At the township scale, among Gansu’ s 1,034 townships, 634 have cold and cool climates, with 274 townships having cold and cool zone area proportions above 50%. Most townships have potential for cold and cool agriculture development.

Due to spatial scale effects, counties with low cold and cool zone area proportions still contain townships with high proportions internally, such as Liangzhou District and Gulang County in Wuwei City, and Huangmen Township and Jinji Town in Tianshui City. Therefore, to avoid underestimating townships with greater cold and cool characteristic agricultural development potential during statistics, identifying cold and cool advantage regions at finer scales is necessary.

3.2 Agricultural Development Types in Gansu’ s Cold and Cool Zones

To further develop and utilize cold and cool agricultural resources, agricultural development type identification, development direction, and pathway 研判 were conducted within Gansu’ s cold and cool zones. First, based on regional natural resource endowments and consulting Gansu’ s agricultural production layout and comprehensive agricultural zoning, the study adheres to the principles of intra-regional consistency and inter-regional difference to 挖掘 different regional agricultural characteristics and comparative advantages. Second, through combining qualitative analysis with quantitative results, regional agricultural development strategic goals, priorities, and policies are proposed according to regional economic characteristics and agricultural development status. The rationality of regional agricultural structure and layout is evaluated, and suggestions for improving production conditions in deficient areas are provided to formulate targeted development strategies tailored to local conditions.

Based on differentiated natural environmental indicators and land cover proportions, Gansu’ s cold and cool zone agricultural development types can be divided into seven categories: four pastoral types (Beishan Desert Alpine Pastoral Area, Qilian Mountain Dry-Cold Pastoral Area, Loess Plateau Dry-Cool Pastoral

Area, Gannan Plateau Wet-Cold Pastoral Area), one cultivation type (Hexi Corridor Warm-Cool Cultivation Area), and two mixed types (Longzhong Mountain Warm-Cool Agro-Pastoral Area, Longnan Mountain Wet-Cold Agro-Forestry-Pastoral Area). To ensure complete analysis at township and district/county administrative boundaries, grid units were intersected with districts/counties and townships. The agricultural type with the largest grid area proportion in each region was selected as the dominant agricultural type (Figure 7). Statistical analysis based on 1 km grid units shows that cold and cool pastoral, cultivation, and mixed agriculture account for 56.22%, 27.49%, and 16.30% respectively. At the township and district/county scales, the Hexi Corridor Warm-Cool Cultivation Area (type V) has the highest proportion of cultivation types, with nearly 30% of townships and districts capable of developing cold and cool cultivation.

3.2.1 Pastoral Types **Beishan Desert Alpine Pastoral Area (I)** covers 14,278 km^2 (8.44%), primarily located in the Altun Mountain area at the western end of the Qilian Mountains. The region has high desert proportion, with grassland accounting for only 12.93% as desert and semi-desert grassland of average quality. Annual average temperature is -5~8°C, water sources are scarce, but annual sunshine hours reach 3,000 h. The region should prioritize vegetation restoration and shelterbelt establishment while continuously "reclaiming wasteland" to expand high-quality forage planting areas and gradually improve grassland ecosystems. Livestock breed selection should focus on camels, goats, and lambskin sheep with high roughage tolerance and production performance.

Qilian Mountain Dry-Cold Pastoral Area (II) covers 21,870 km^2, mainly located in Zhangye, Jinchang, and Wuwei cities, with larger proportions in Tianzhu and Sunan counties. Elevations are mostly below 3,500 m, with poor heat conditions but high dry matter and mineral content in forage. The main issue is the scarcity of natural grazing land, low grass yield and livestock carrying capacity per unit area, and primary dependence on farmland for livestock. The region should prioritize rational utilization of natural grasslands through rotational grazing and promotion of pastoral mechanization. Simultaneously, while selecting and breeding local varieties, introducing external improved breeds for crossbreeding can enhance local breed performance, developing cattle toward dual-purpose meat and dairy, improving sheep wool and meat production, and truly achieving equal emphasis on quantity and quality.

Loess Plateau Dry-Cool Pastoral Area (III) covers 44,511 km^2 (26.32%), mainly distributed in the Hexi Corridor, northern Longzhong, and northern Huanxian, represented by Gulang and Jingyuan counties. The region has high average elevation of 1,784 m, large monthly diurnal temperature difference of 15.7°C, and nearly 2,700 h of annual sunshine hours, providing superior light-heat conditions favorable for organic matter accumulation with absolute advantages for animal husbandry. The Xinglong Mountain, Maxian Mountain, and Liancheng areas have good forest and grassland coverage, with vast grasslands and mountainous areas suitable for grazing, serving as the main production area for fur sheep (Tan sheep, Shamao goats). Jingtai and Gulang counties' Sanbei sheep are relatively famous, requiring attention to local breed selection and preservation of their genetic characteristics.

Gannan Plateau Wet-Cold Pastoral Area (IV) covers 27,567 km^2 (16.30%), concentrated in Gannan Prefecture, Xiahe, Zhuoni, and Lintan counties with larger proportions. The region has large topographic relief, primarily sloping grassland, with annual average temperature of -5~8°C and poor heat conditions. However, the climate is humid with abundant water and lush grass, providing high grass yield and livestock carrying capacity, with rich wildlife resources. This area possesses numerous quality livestock products: the dual-purpose Yak and "Hequ Horse" are excellent breeds in China; "Oula Sheep" and "Ganjia Sheep" are high-quality Tibetan sheep for both meat and wool; Lintan County' s "Black Purple Lamb" is one of Gansu' s better fur sheep breeds; and Minxian "Lüjing Pig" has tender meat and thin skin, representing a high-quality meat source for processing bacon and ham, all deserving increased investment and development.

3.2.2 Cultivation Type Hexi Corridor Warm-Cool Cultivation Area (V) covers 27,567 km^2 (16.30%), concentrated in Linxia Prefecture, Tianshui, Pingliang, and Dingxi cities, distributed in scattered strips along the Hexi Corridor. Average elevation is approximately 1,700 m, with sloping and dryland fields. Monthly diurnal temperature difference reaches 15.7°C, and \$ \$10°C accumulated temperature is 2,452°C, making it the type area with the highest light-temperature production potential among all types, giving cultivation significant advantages. Premium quality products include Lemin purple garlic, Jinchang radish, Yuzhong cabbage, Ningxian walnut, and Tianshui Huaniu apple, all nationally top-quality agricultural products. Shallow mountainous areas can plant highland barley, potatoes, and oats, while higher altitude areas can promote characteristic vegetables such as plateau summer vegetables and silage corn, as well as economic crops like oilseeds, hemp, and medicinal materials for higher economic returns.

3.2.3 Mixed Types Longzhong Mountain Warm-Cool Agro-Pastoral Area (VI) covers 34,020 km^2 (20.12%), mainly distributed in central-southern Longzhong and eastern Ganson, represented by Yongjing, Huining, and Huachi counties. Average elevation is 1,700 m with large monthly diurnal temperature difference and good light-heat resources. The area primarily consists of dryland fields with extensive pastoral management and low productivity. A semi-agricultural, semi-pastoral economic model is recommended. Agricultural area animal husbandry should combine stall-feeding with grazing to improve productivity of local excellent breeds such as station sheep, Tan sheep, Shamao goats, and "Qingyang Donkey." Cultivation should focus on promoting drought-resistant and cold-tolerant crops (rye, potatoes, and legumes) and grass-grain rotation, increasing planting areas for crop straw, green manure, and alfalfa to accelerate soil fertility improvement while ensuring forage supply.

Longnan Mountain Wet-Cold Agro-Forestry-Pastoral Area (VII) has the smallest proportion at only 12,459 km^2 (7.37%), represented by Weiyuan, Lintao, and Zhang counties. Heat resources are relatively scarce, with the largest slope and topographic relief, belonging to an integrated agro-forestry-pastoral zone. Agricultural development needs to 开辟 a development path of "grass before forest, grain-grass rotation, breeding-driven planting, and planting-driven breeding." Steep slope cultivated land should gradually be returned to grass and trees to increase the proportion of forestry and animal husbandry. Simultaneously, attention should be paid to forage and feed production, using green manure crops to replace fallow land for developing animal husbandry. The Ziwu Ridge forest area in this zone is cool and humid with rich biological resources, suitable for valuable Chinese medicinal materials such as cordyceps and deer antler. Forestry focuses on fuelwood and soil conservation forests, achieving intercropping of forest-grain and forest-oil.

3.3 Comprehensive Development Pathways for Cold and Cool Resources in Gansu Province

The essence of agricultural resource development and utilization in cold and cool zones lies in understanding the ecological type patterns and resource endowment characteristics of cold and cool mountainous areas, combining food security guarantee targets and important agricultural product market demand factors to rationally plan different types of land functional zones within cold and cool zones. This improves adaptability and capacity for production and management activities using cold and cool resources, achieving a virtuous cycle of regional ecology and economy.

Specifically, first, agricultural industrial structure should be optimized according to local conditions. In agricultural production, reduce the proportion of land resource-intensive agricultural products such as grain, cotton, and oil, and increase investment and support for high-quality labor-intensive products such as fruits, vegetables, and tea, as well as livestock breeding and processing industries, leveraging the comparative advantages of western regions like Gansu. For example, utilize the province' s extensive high-altitude cold and cool climate advantages to develop off-season vegetable cultivation, establishing a national "vegetable basket" supply base to achieve east-west complementarity in national vegetable production. Utilize rare local livestock breeds grown under the dry-cold conditions of high-altitude grasslands to create characteristic agricultural and livestock brands such as "Millennium Mutton Township Minqin"and "Tianzhu White Yak," transforming from single grain production to integrated agro-forestry-pastoral management and accelerating the construction of scaled and specialized production bases to exert multiplier effects on input-output.

Second, leverage regional competitive advantages to optimize crop product structure and improve market competitiveness and comprehensive economic benefits through "quality-driven agriculture." With superior natural resource endowments in northwestern China, vigorously develop green, organic, and safe food. By introducing, transforming, and promoting improved varieties, maximize strengths and circumvent weaknesses to form high-end agricultural product industry chains. For example, increase deep 挖掘 of "famous, special, rare, and excellent" agricultural resources in cold and cool mountainous areas. Based on unique characteristic resources and cultural connotations of different regions, create geographical indication agricultural products such as "Huining Oats," "Minle Purple Garlic," and "Dingxi Potatoes" to meet consumer demand for high-quality, nutrient-rich food. Promote the transformation of "mountain goods" into "premium goods" through quality improvement and value addition, gradually advancing cold and cool mountainous agriculture dominated by forestry and animal husbandry toward regional layout, scaled production, and industrialized management, achieving a "Chinese rice bowl" through cold and cool economy.

In conclusion, while ensuring stable national grain output, Gansu Province must respect farmers' willingness and planting traditions. By adhering to both expanding agricultural development space and enhancing agricultural development quality, gradually form a modern agricultural production structure and regional layout adapted to market demand and resource-environment carrying capacity. With characteristic and differentiated development concepts, promote regionalization of cold and cool agricultural production, specialization of quality products, and sustainable management development. This addresses the long-standing structural problem in China' s agricultural market of surplus staple grains alongside shortages of quality agricultural products, driving innovation in the national food supply system.

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4. Discussion

In recent years, structural convergence still exists in China's agricultural regional layout adjustments, with characteristic agricultural regional layout and industrial specialization yet to be formed, failing to fully leverage regional comparative advantages. Agricultural production structure adjustments lag behind the needs of ensuring greater food security. Although traditional grain-dominated agricultural regions harvest abundantly year after year, they fall into the trap of "increased production without increased income." The fundamental reason lies in the mismatch between the production structure that one-sidedly pursues grain yield increases and the continuously upgrading food demand structure, with agricultural production structure adjustments lagging behind the needs of ensuring "Greater Food" security.

China' s mountainous areas occupy 69.8% of total national territory, involving over 1,500 counties. These regions are both important production areas for grain and characteristic agricultural products and concentrated areas for relatively impoverished populations. Due to special geographical landforms limiting traditional field agriculture development, gradually forming a mountainous agricultural economic pattern adapted to cold and cool resource characteristics and promoting transformation of agricultural production from high-yield to high-quality types represents an important pathway for western mountainous areas to transform agricultural development modes and narrow economic development gaps with developed regions.

Cold and cool resources represent a "new resource" not yet developed on a large scale, with application scope and forms in new industries still in the exploration stage, and suitable industry types varying across regions. How to utilize this "new resource" to find the most suitable green industries for local agricultural development requires deeper investigation from government and academia. Future research should continue cold and cool zone identification and development across different provinces, cities, and counties nationwide. By synthesizing characteristics and pathways of cold and cool agricultural development and utilization at different scales across regions, explore sustainable paths for multi-scale and multi-type high-quality cold and cool agricultural development. Theoretically, this would enrich the scientific system for cold and cool agricultural resource identification, development, and utilization. Practically, it would clarify the status and role of cold and cool agriculture within China' s agricultural development system, establishing technical specification systems and typical model demonstrations for advantageous cold and cool region development nationwide to guide agricultural high-quality development.

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5. Conclusion

This study constructs a theoretical framework for cold and cool agricultural resource development guided by the holistic "Greater Food" approach. Through overlay analysis of eight categories of natural indicators, 169,249 grid units of cold and cool climate zones in Gansu Province were identified, covering an area of approximately 1.69$×10^{5}$ km^2, accounting for 41.97% of the province' s total land area. An agricultural functional zoning index system reflecting natural conditions was constructed from eight specific indicators, dividing Gansu' s cold and cool zones into seven agricultural development types: Beishan Desert Alpine Pastoral Area, Qilian Mountain Dry-Cold Pastoral Area, Loess Plateau Dry-Cool Pastoral Area, Gannan Plateau Wet-Cold Pastoral Area, Hexi Corridor Warm-Cool Cultivation Area, Longzhong Mountain Warm-Cool Agro-Pastoral Area, and Longnan Mountain Wet-Cold Agro-Forestry-Pastoral Area.

Among the seven types, four are pastoral, one is cultivation, and two are agro-pastoral mixed types. Based on 1 km grid unit statistics, cold and cool pastoral, cultivation, and mixed agriculture account for 56.22%, 27.49%, and 16.30% respectively. At the administrative unit scale, the proportions of townships and districts capable of developing these three major agricultural types are relatively balanced, each representing approximately 30%.

Agricultural regional division of labor and specialization based on natural condition possibilities is the necessary path to achieve modern agricultural high-quality development. During cold and cool zone development, Gansu Province should promote differentiated advancement by zones and categories, reducing traditional crop areas and improving planting varieties and structures on cultivated land; establishing off-season organic vegetable bases in forest land; and creating quality livestock 新业态 in grassland to form a cold and cool characteristic agricultural production structure and regional layout matching market demand.

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Note: Figure translations are in progress. See original paper for figures.