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Spatial differences of specialty agriculture development in the mountainous areas of China -- "one village, one product" as an example

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ABSTRACT

With the rapid development of urbanization, the rate of abandonment of arable land in China's mountainous areas has accelerated. Solving the phenomenon of abandonment of arable land has become an important issue in managing the use of China's arable land, the key to which lies in the development of specialty agriculture using the unique natural environment of mountainous areas. This paper scrutinizes both the horizontal and vertical distribution of specialty agriculture in these areas, drawing upon the "One Village, One Product" dataset provided by the Chinese Ministry of Agriculture and Rural Development. The findings reveal that the horizontal distribution pattern of specialty agriculture exhibits the formation of eight primary clusters. It is intriguing to observe that a majority of these clusters are situated at the intersection of two or three provincial administrative units, with the largest cluster occurring at the border of Chengdu and Chongqing. In terms of the vertical distribution pattern, the specialty agriculture in China's mountainous areas are mainly distributed at low altitudes, i.e., below 500 m, and at gentle slopes of 4°–8°, and with increases in altitude or slope, the overall amount of specialty agriculture declines rapidly.

1. Introduction

Rapid urbanization has resulted in a massive migration of people from the mountainous areas of China. However, since it is limited by the large slope of mountainous arable land, a high degree of plot fragmentation, and the relatively backward infrastructure facilities such as farmland water conservancy, the level of large-scale farming operations in mountainous areas is difficult to significantly increase [1–3]. Furthermore, the difficulty in disseminating agricultural technology, compounded by ineffective farmland management practices, has triggered extensive abandonment of arable land within these regions [4,5]. As per a national survey conducted amongst farming households, the abandonment rate of arable land in China's mountainous areas stood at 14.32% during 2014–2015, corresponding to a total abandoned area of approximately 66,700 km^2 [6].

The cultivation of specialty agriculture has emerged as an effective stratagem to mitigate the issue of land abandonment in

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mountainous areas. While the fragmented nature of arable land and other unfavorable circumstances hinder large-scale agricultural production in these areas, the unique combination of climatic conditions, soil types, availability of clean water, and low pollution levels present notable opportunities for the growth of high-quality specialty agriculture [7,8]. Numerous nations are now fostering the advancement of specialty agriculture in accordance with their specific natural conditions, population needs, and sociocultural contexts. For example, the "One Village One Product" and "Saemaeul Movement" in Japan and South Korea represent the development of specialty agriculture in the context of scarcity of arable land and local adaptation [9,10], resource-oriented and tourism agriculture in the US in the context of labor scarcity [11,12], while Germany emphasizes optimizing variety selection and upgrading agriculture according to industrial demands [13,14].

Encompassing approximately two-thirds of China's total land area, the country's mountainous areas present considerable diversity in terms of topographical distribution and climatic conditions, leading to varying agricultural practices and conditions [15,16]. In 2011, the Ministry of Agriculture and Rural Affairs of China (MARAC) initiated the first set of "One Village One Product" demonstration villages and towns (OVOP-DVTs). This program is designed to capitalize on the distinct resource advantages and potential inherent in mountain agriculture. It seeks to tailor production and developmental objectives within these areas based on local conditions, with the goal of fostering competitive, characteristic mountain agriculture, sustaining small-scale farming, and endorsing inclusive development. This system will not only increase farmers' incomes, but also increase their motivation to farm. While actively promoting the Food and Agriculture Organization's (FAO) 2030 Agenda for Sustainable Development, it alleviates the problem of abandonment in mountainous areas and promotes the revitalization of rural China [17–19].

The prevalent surge of geospatial big data presents a valuable prospect for investigating specialty agriculture in terms of spatial patterns. Yet, the majority of existing research on specialty agriculture predominantly concentrates on qualitative studies, encompassing rural development transformation, spatial reconstruction, and environmental evolution [20–22]. Furthermore, these explorations are often confined to provincial and municipal regions. A limited number of scholars have ventured into quantitative analyses of specialty agriculture [23,24]. Notably, there exists a significant lacuna in systematic qualitative and quantitative investigations addressing the disparities in the horizontal and vertical spatial distribution of specialty agriculture in mountainous areas at a national scale.

In view of this shortcoming, this study investigates the common trends and differentiation in the horizontal and vertical spatial distribution of specialty agriculture in China's mountainous areas. The investigation is grounded in an analysis of OVOP-DVTs dataset, incorporating GIS spatial analysis and quantitative statistics to discern distribution density and pattern characteristics. While pursuing a comprehensive understanding of the specialty agriculture layout, the study provides scientific Chinese experience for FAO to accomplish the 2030 Sustainable Development Goals (SDGs) for food and agriculture.

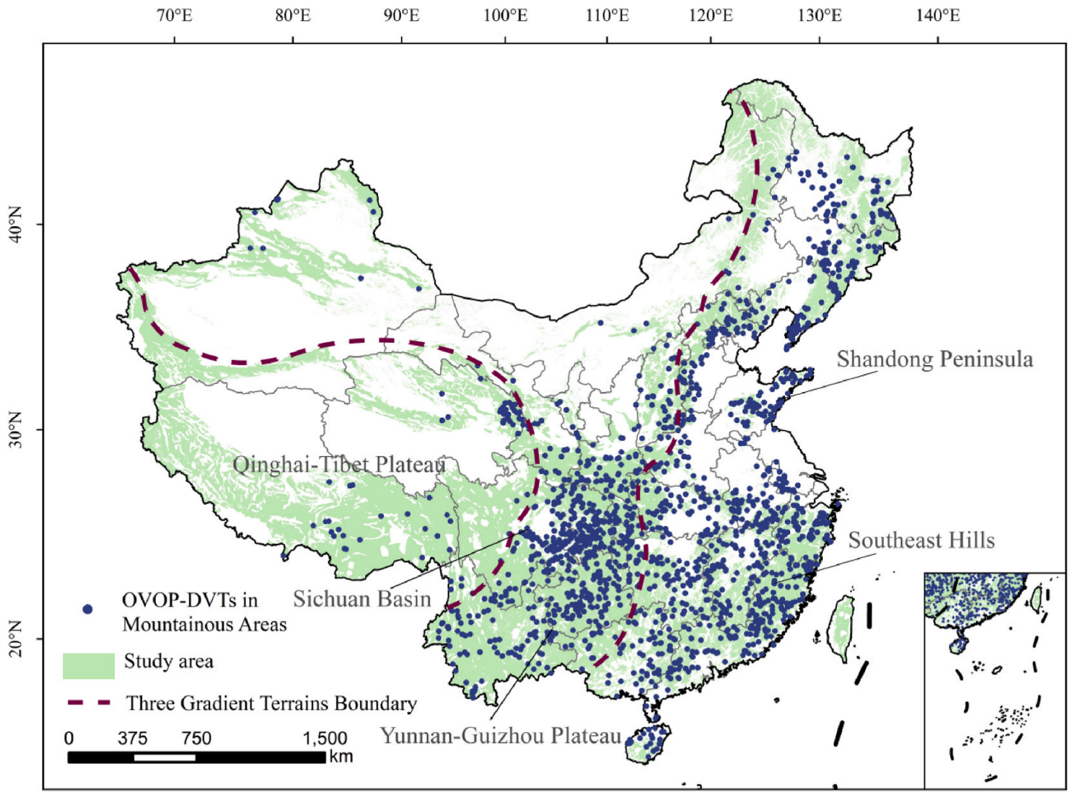

Fig. 1. Spatial distribution of OVOP-DVTs in the mountainous areas in China.

2. Materials and methods

2.1. Study area

The topography of China is complex and diverse, and various terrains are intertwined with each other. On the whole, according to the altitude from west to east, it can be divided into three gradient terrains. The first gradient terrain is mainly dominated by very high mountains (Qinghai-Tibet Plateau) with altitudes greater than 5000 m; intermediate elevation mountains with altitudes of 1000–3000 m (Yunnan-Guizhou Plateau, Sichuan Basin) are mainly distributed on the second gradient terrain; and low mountains (Shandong Peninsula) with altitudes of 500–1000 m and hills (Southeast Hills) with altitudes <500 m are mainly distributed in the third terrain. There is no uniform definition of the extent of mountainous areas in China in academic circles [25]. Since areas with a slope of less than 2° are regarded as flat land in the Technical Regulations for Current Land Use Survey promulgated in 1984, the study area was obtained by eliminating the regions with slope ≤2° based on the 1:400,000-scale vector map of China's mountainous areas. That map was provided by the State Key Laboratory of Resource and Environmental Information System of the Chinese Academy of Sciences (CAS). The area with a slope ≤2° was obtained based on ASTER GDEM 30 M resolution digital elevation data after processing. Ultimately, the study area covers about 4 million km^2 (Fig. 1).

2.2. Data sources

The research data include two main components. (1) OVOP-DVTs in mountainous areas. These data were obtained from the official website of MARAC (http://www.moa.gov.cn/). As of December 31, 2021, a total of 3,786 samples were collected with specific location and product information. Among them, 1,725 samples are in mountainous areas. (2) Basic geographic information data. The maps of administrative boundaries and rivers in the study area were obtained from the Data Sharing Center of the Institute of Geographical Sciences and Resources, CAS; and the data of elevation and slope were obtained from ASTER GDEM 30 M of Geospatial Data Cloud and processed by ArcGIS 10.7.

2.3. Kernel density estimation

The kernel density estimation method is a non-parametric estimation method. It starts with the data sample itself, and it can solve the problem of a large gap between the basic assumptions in the parametric estimation model and the actual physical model, and also intuitively reflect the intensity of a kernel's influence on the surrounding area. Its calculation formula is:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right) \quad (1)$$

where $f(x)$ is the kernel density estimate, $k\left(\frac{X-X_i}{h}\right)$ is the kernel density function, h is the bandwidth, and $X - X_i$ denotes the distance from the valuation point X to the event X_i. A larger $f(x)$ means denser points, and a higher probability of regional events.

Table 1
Classification criteria of Specialty agriculture.

Major Categories	Sub-categories	Specific products
Specialty Planting	Food	Rice, Wheat, Corn, Sorghum, etc.
	Cotton and flax	Cotton, Jute, Kenaf, Ramie, Flax, etc.
	Tobacco	Yellow tobacco, Flue-cured tobacco, etc.
	Medicinal materials	Ginseng Polygonum multiflorum, Coptis chinensis, Ganoderma lucidum, etc.
	Vegetables	Asparagus, Radish, Eggplant, Melons, Lotus seeds, Cabbage, etc.
	Truffles	Black Fungus, Shiitake Mushroom, Pleurotus eryngii, Hericium erinaceus, etc.
	Tea	Black tea, Green tea, Oolong tea, Pu'er tea, etc.
	Fruits	Apple, Pear, Citrus, Orange, Banana, Strawberry, Kiwi, etc.
	Nuts	Peanuts, Walnuts, Melon seeds, Torreya, etc.
	Flower seedlings	Roses, Peonies, Camellias, Chrysanthemums, Potted flowers, etc.
	Other crops	Green manure crops, Feed crops
Specialty Breeding	Livestock	Chicken, Duck, Pig, Goose, Sheep, Cattle, Pigeon, Rabbit, etc.
	Aquatic	Turtle, Fish, Crab, Sea cucumber, Clam, Shrimp, Oyster, etc.
	Special types	Silkworms, Crickets, Bees, etc.
Specialty Food	Fresh	Beef, Mutton, Eggs, Honey, Seafood, Donkey meat, etc.
	Processed	Rice products, Meat products, Fried products, Oil products, Wine products, etc.
Specialty Culture	Handicraft processing	Buddha beads, Buddha statues, Bamboo and wood products, Grass products, etc.
	Folk culture	Stone carving, Singing and dancing, New Year Paintings, etc.
New Business	Leisure business	Leisure agriculture, Ecotourism, Farmhouse recreation, Fisherman recreation, etc.
	Combination of farming and livestock	Rice shrimp continuous cropping, Rice fishing, etc.
	Electronic commerce	Eiderdown e-commerce

Note: Specialty agriculture refers to the above specific categories for the leading industries and the advantages of distinctive features, significant quality and efficiency, and the basic realization of the integrated development of production and village, with a strong radiation-driven role.

2.4. Specialty agricultural classification standards

The classification of specialty agriculture has been the subject of several scholarly studies, each proposing a unique set of criteria. Bai [26], for instance, proposed a tripartite system comprising natural resource-based, enterprise processing, and industrial culture-based modes. Similarly, Cheng et al. [27] offered a three-mode division incorporating branded development, industrial development and ecological agricultural development. Chen et al. [28], in alignment with the "National Economic Classification (GB/T4 754–2017)" national standard, categorized the dominant industries of OVOP-DVTs into five categories: agriculture, forestry, animal husbandry, fishery, and others.

In this study, the classification framework developed by MARAC in 2021 was adopted. This framework presents five major categories and 21 sub-categories of OVOP-DVTs (Table 1). Utilizing these classification standards, the 1,725 mountain specialty agricultural locations were systematically categorized into five primary categories: specialty planting, specialty breeding, specialty food, specialty culture, and new business.

3. Results

3.1. Horizontal distribution of specialty agriculture

Spatial variations in China's population, marked by the "Hu Huanyong Line (Hu line)" [29], significantly influence the agricultural cultivation landscape. Notably, Fig. 2(a–f) illustrates a stark distinction between the eastern and western sides of the "Hu Line". In the mountainous areas east of this demarcation, 1,598 OVOP-DVTs exist, comprising 92.6% of the total within the study area. Interestingly, these areas account for only 54.35% of the total land area, highlighting the intensity of agricultural activities here.

The composition of each category of specialty agriculture also varies across the "Hu line". In the eastern regions, specialty planting is dominant, representing an impressive 87.5% of the agricultural activities, with specialty breeding trailing at 6.0%. Contrastingly, the western regions display a reduced prevalence of specialty planting at 65.4%. However, specialty breeding activities significantly

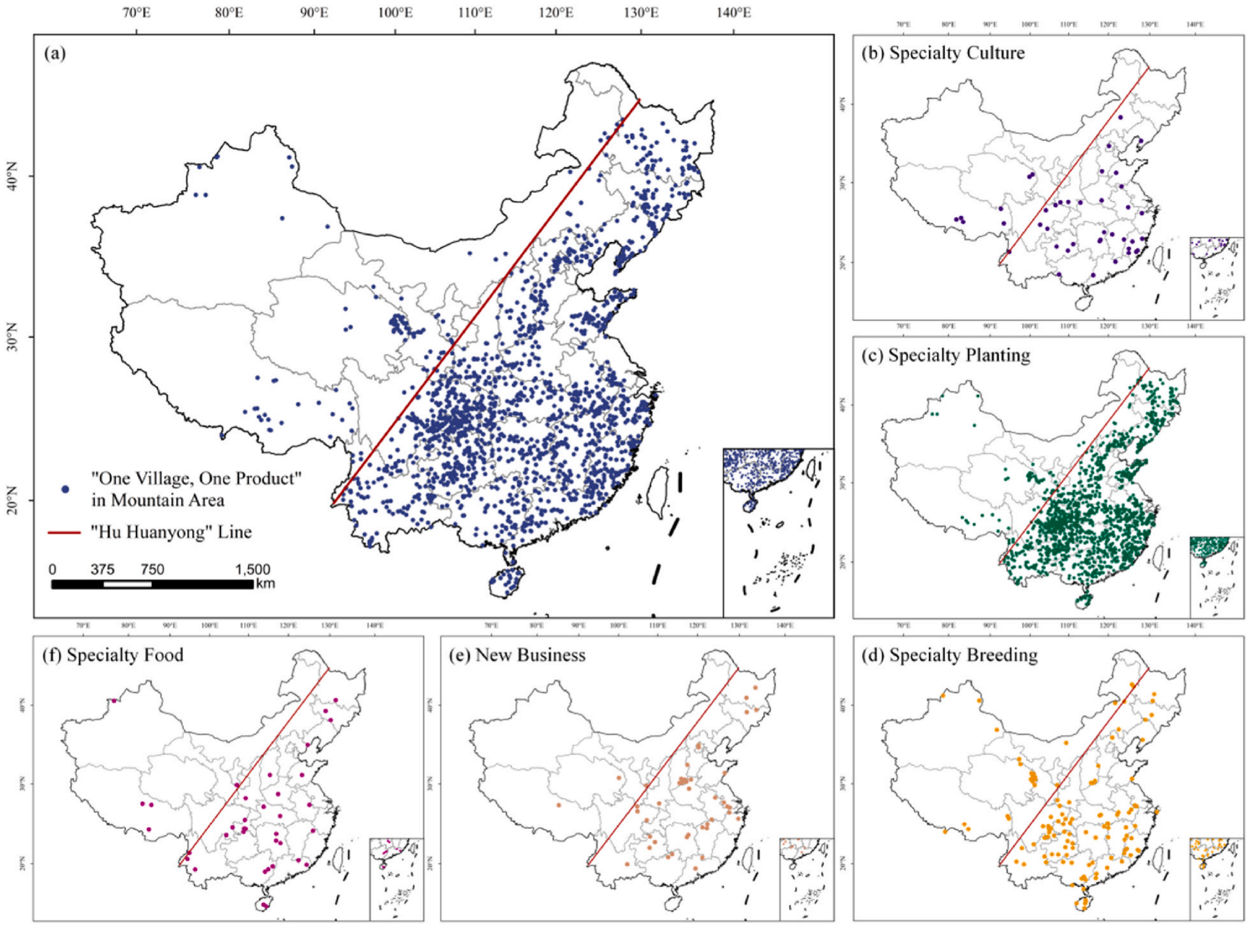

Fig. 2. Schematic diagram of the spatial distribution of (a) overall specialty agriculture and (b) specialty culture, (c) specialty planting, (d) specialty breeding, (e) new business, (f) specialty food, five categories in the mountainous areas on both sides of the "Hu Line".

increase, making up 20.5% of the agriculture activities, a value noticeably higher than in the eastern part. This spatial differentiation underlines the unique agricultural landscapes delineated by the "Hu line".

Furthermore, OVOP-DVTs in the mountainous areas were categorized based on a conventional regional division method, resulting in four major sectors: eastern, western, central, and northeastern. The results indicated that the western region hosted the majority of OVOP-DVTs, comprising 43.7% of the total as shown in Fig. 3. The eastern and central regions exhibited comparable proportions, accounting for 24.8% and 22.3% respectively.

Across all regions, specialty planting maintained a dominant role, comprising more than 85.0% of agricultural activities, followed by specialty breeding, which constituted approximately 5.0%. Nevertheless, beyond specialty breeding and planting, the regional profiles of specialty agriculture displayed notable differences. For example, specialty culture accounts for the largest proportion in the eastern and western regions, while the central and northeast regions have the largest share of new business categories. This suggests the existence of distinct regional characteristics in specialty agriculture across various areas.

3.2. Kernel density of specialty agriculture distribution

Kernel density estimation methods reveal an intriguing distribution pattern of specialty agriculture in China's mountainous regions, forming eight circles. These circles predominantly locate themselves along the boundaries of two or three provincial administrative divisions. The most substantial cluster emerges in the border area of Chengdu and Chongqing (Fig. 4). Remarkably, none of these major agricultural circles are situated in the northwest of the country.

3.3. Distribution across elevations

Altitude significantly influences the rural production environment [30,31], and thus affects the spatial distribution of mountain specialty agriculture. As depicted in Fig. 5, the third terrain exhibits the highest concentration of OVOP-DVTs within mountainous

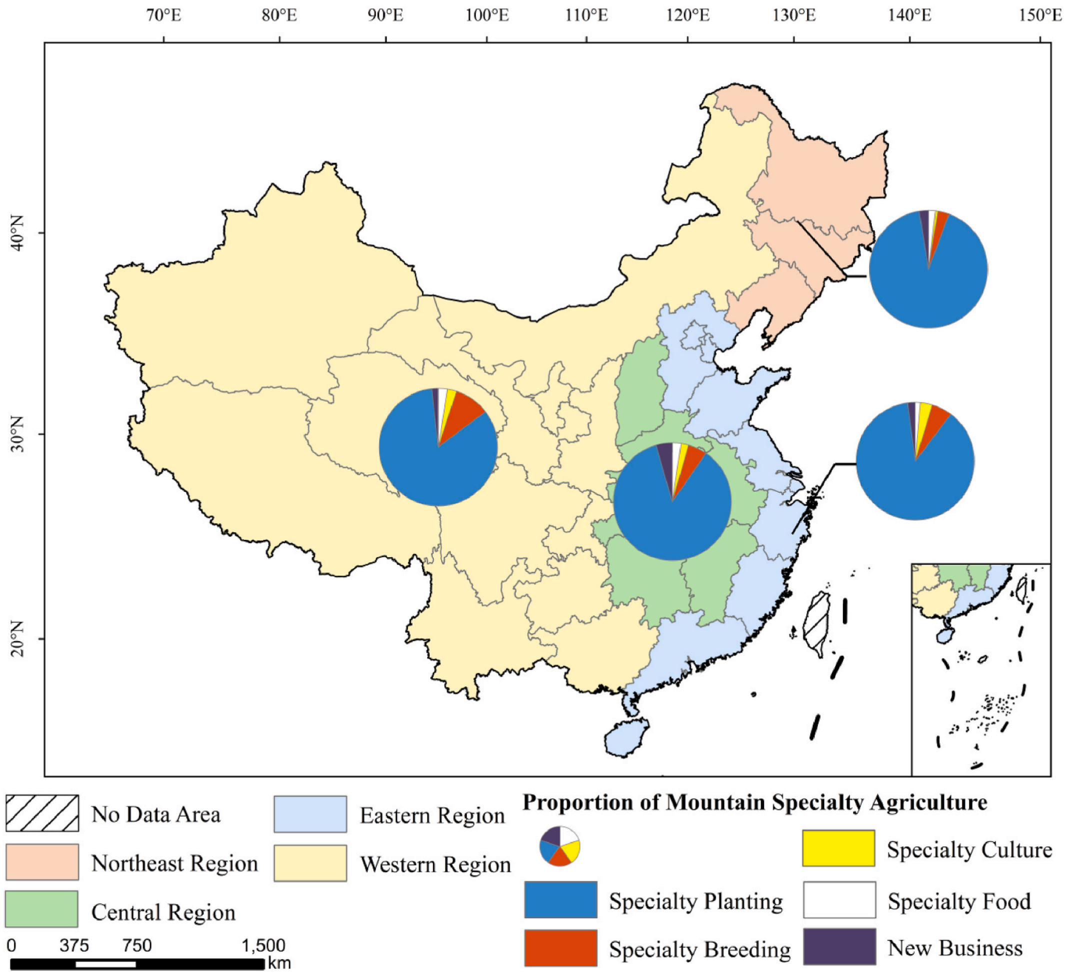

Fig. 3. Structural compositions of specialty agricultural categories in the different regions.

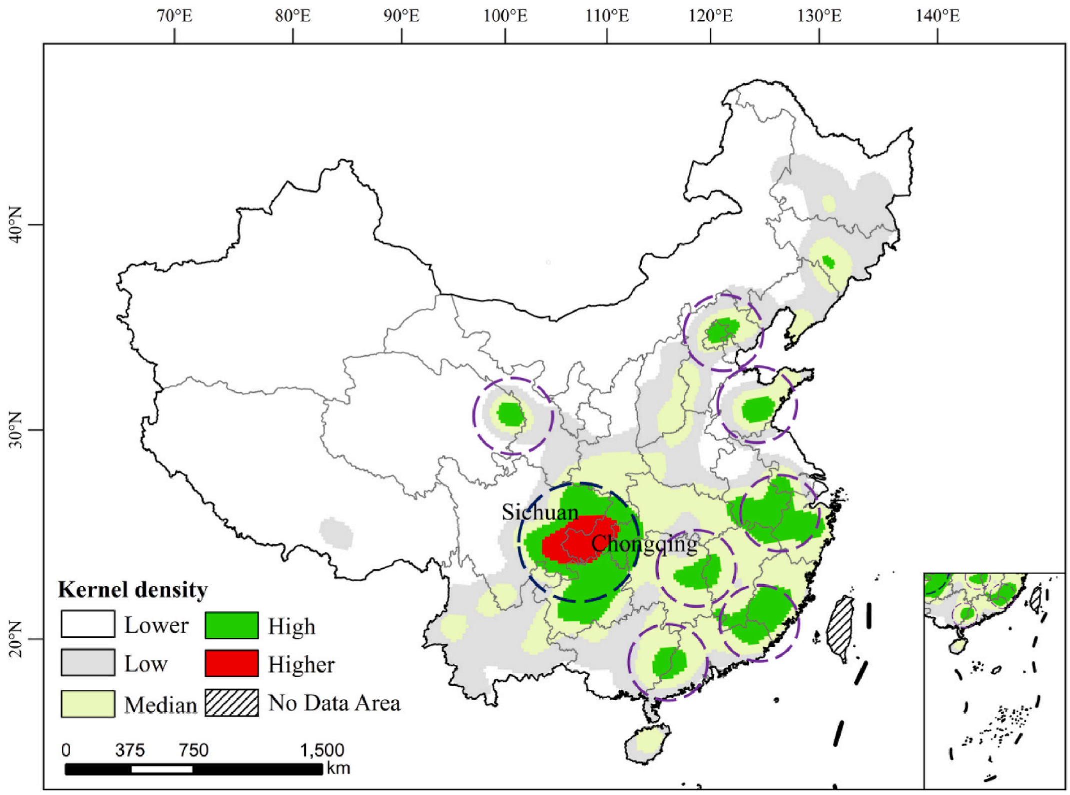

Fig. 4. Distribution of the nuclear density of specialty agriculture in the mountainous areas.

areas, comprising 58% of the total. This concentration is particularly evident in the Shandong Peninsula and Southeastern Hills. On the second terrain, clusters of OVOP-DVTs are prominent in the Sichuan Basin and the Yunnan-Guizhou Plateau. Interestingly, the first terrain presents the sparsest distribution of OVOP-DVTs in mountainous areas.

Further classification of the mountainous areas according to altitude reveals five distinct regions: <200 m, 200–500 m, 500–1000 m, 1000–2000 m, and >2000 m. The majority of OVOP-DVTs in China's mountainous areas reside at altitudes <500 m, representing 60.5% of the total. The box-line map (Fig. 6) displays relatively similar distributions of specialty agriculture categories, primarily within areas with altitudes between 100 and 1000 m. However, specialty food and specialty planting exhibit a slightly different distribution, being found in altitudes spanning 200–1300 m and 150–800 m, respectively. Notably, the median value for each specialty agriculture category falls within the lower quartile, suggesting a strong tendency for these categories to gravitate towards lower altitude areas.

3.4. Distribution across slopes

In alignment with the slope classification standard of arable land stipulated in the Technical Regulations of the Current Land Use Survey, and considering the distribution characteristics of specialty agriculture, slopes were categorized into four intervals: <8°, 8°–15°, 15°–25°, and >25°. The results indicate that the majority of OVOP-DVTs were situated in areas with slopes of <8°, representing 41.0% of the total (Fig. 7 (a - e)). Conversely, areas with slopes exceeding 25° hosted the fewest OVOP-DVTs, accounting for more than 10.4% of the total.

Furthermore, an intriguing trend was noted across all categories of specialty agriculture: the frequency increased with the slope, peaking at approximately 6° (Fig. 7(a–e)). Beyond this point, as the slope steepened, the presence of specialty agriculture demonstrated a fluctuating decrease. This suggests a correlation between the slope of the land and the concentration of specialty agricultural activities.

4. Discussion

This study systematically analyzed the horizontal distribution and vertical differences of OVOP-DVTs in the mountainous areas of China. The results give some insight into the causative factors and provide some policy implications for its development.

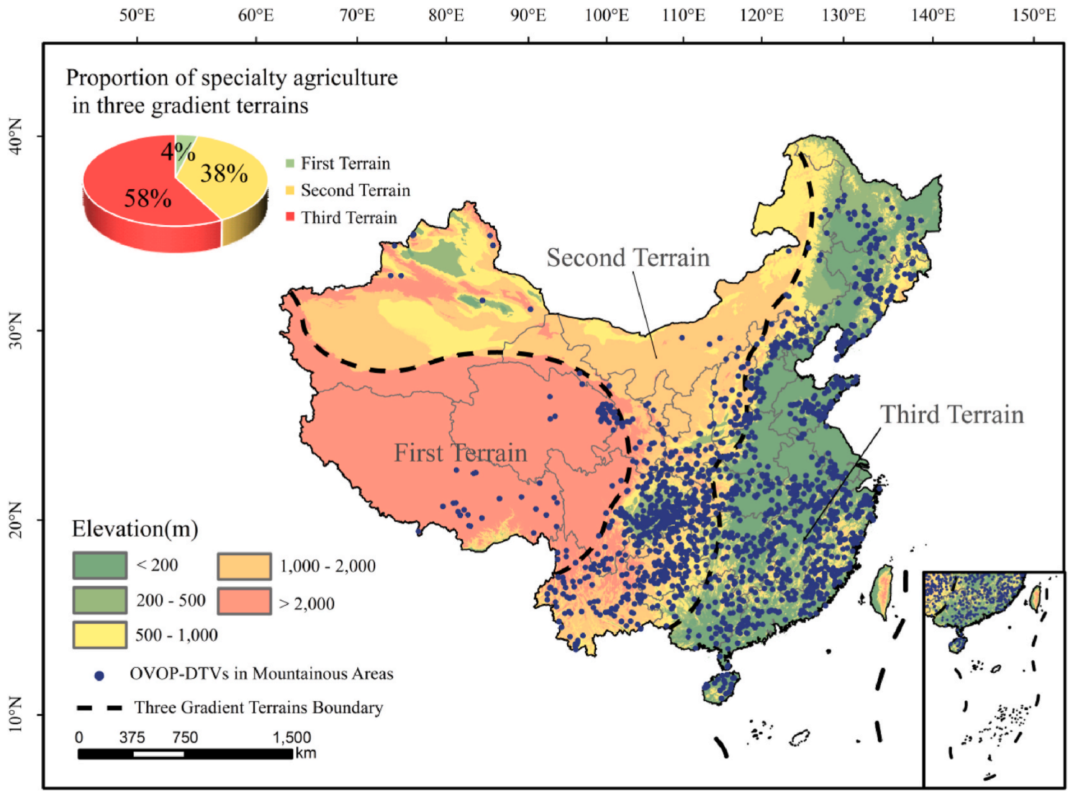

Fig. 5. Spatial distribution of OVOP-DVTs in mountainous areas at different elevations in China.

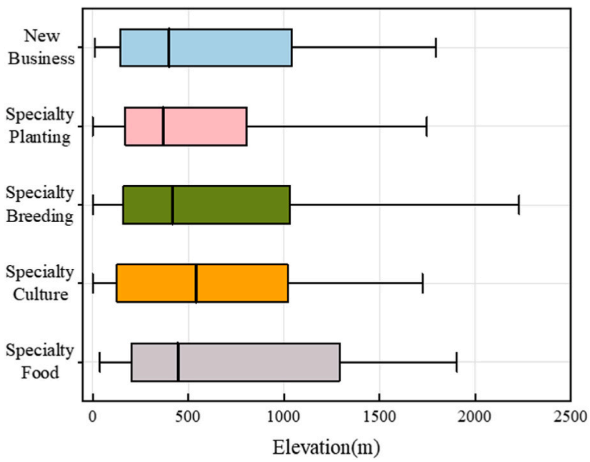

Fig. 6. Box line plot of the elevation distribution of each specialty agricultural category in the mountainous areas.

4.1. Impacts of urban areas on the distribution of specialty agriculture

China's cities are mainly located along the eastern coast and along the Yangtze River economic Corridor, which has been highlighted in many studies [31,32]. This study also found that there is a general tendency for the layout of specialty agriculture in China's mountainous areas to be closely integrated with urban areas (Fig. 8). Urbanization and increased population density have depleted the natural landscape in urban areas, igniting a desire for urban dwellers to reconnect with nature and, consequently, an increased demand for rural specialty agricultural products [33]. This particular form of agriculture not only provides urban consumers with high-quality products, but also an expansive natural environment that can alleviate chronic stress and anxiety [34,35]. In addition, it provides a high-quality place for leisure, recreation, and relaxation [36]. Over the past decade, studies have shown a global upward trend in visits

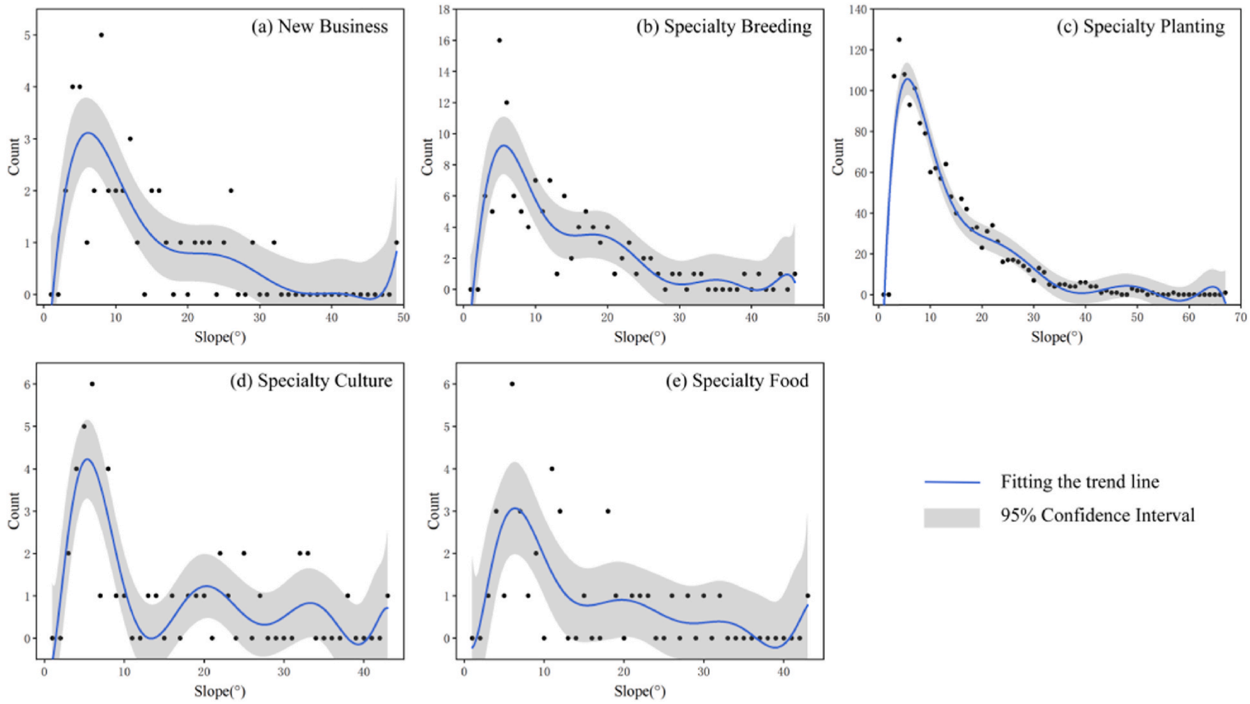

Fig. 7. Scatterplot showing the slope distribution of (a) new business, (b) specialty breeding, (c) specialty planting, (d) specialty culture, and (e) specialty food, five categories of specialty agriculture in mountainous areas.

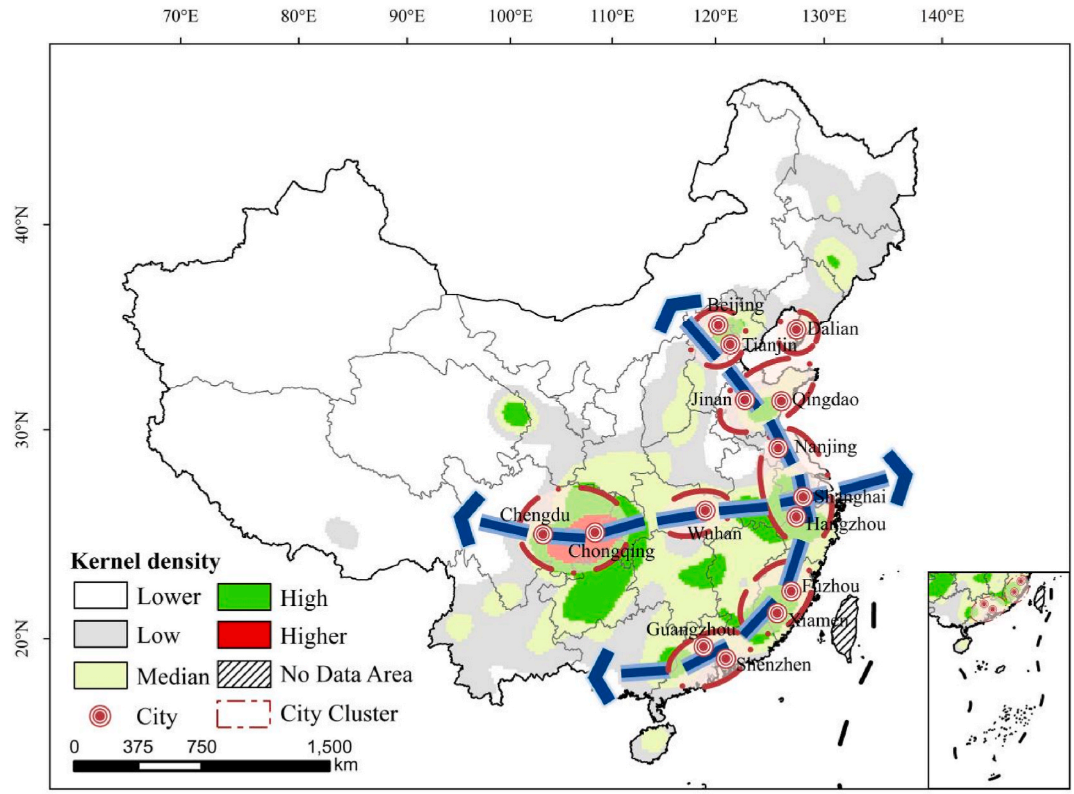

Fig. 8. Distribution of mountain specialty agriculture and urban areas in China.

to tourist parks, fruit picking gardens and other specialty agricultural sites [37,38]. A Study by the University of Tennessee showed a 42% increase in the number of specialty agriculture businesses in the US, from 23,350 in 2007 to 33,161 in 2012 [39]. Such an increase can be attributed to the expansion of public transport and the growing popularity of private cars among urban dwellers, effectively expanding the radius of urban life. In addition, the relatively low rents, advanced transport infrastructure and cutting-edge refrigeration technology in the surrounding mountainous areas ensure that fresh and specialty produce reaches urban consumers in a timely manner. These factors have stimulated the concentration and development of specialty agriculture in the areas surrounding urban centers. Of the eight specialty agriculture circles in China, the Chengdu-Chongqing circle is the most prominent, which is linked to the dense mountainous areas of the Chengdu-Chongqing urban area and the large consumer demand for specialty agriculture from the urban population.

4.2. Consolidation of sustainable development goals for specialty agriculture

The study results demonstrate that specialty agriculture in mountainous areas west of the "Hu Line" represents a mere 2.4% of the total. This relatively underdeveloped state of specialty agriculture in the northwestern mountainous areas of China is quite surprising, considering the area's rich natural endowment capabilities. These include ample sunshine hours, high light intensity, and considerable temperature variations between morning and evening [40,41]. For instance, the abundant sunlight in the Alashan League facilitates the growth of premium pokeweed forests and supports the development of an entire industrial chain of Cistanches [42]. The development of small-scale, high-quality mountain agriculture in the areas west of the "Hu Line" is aimed at improving productivity while pursuing high-quality development [43–45], obtaining higher profits, promoting the economic progress of local rural areas, and achieving SDGs. Furthermore, government and related investments should be directed not only toward fostering the planning for mountain agriculture's development in the western region but also towards facilitating a conducive environment for its growth. This could include strengthening infrastructure, such as improving road transport and increasing the layout of agricultural processing and storage facilities. Such strategies could generate more employment opportunities, alleviate poverty, and provide a reference point for worldwide poverty eradication.

In addition, this study also found a paradox in the spatial distribution of China's mountain agriculture, which is primarily situated at lower altitudes and slopes, contradicting the spatial requirements for food cultivation. Given the escalating food insecurity due to climate change, regional conflict, and economic recession [46,47], enhancing agricultural productivity and sustainable food production is critical for mitigating hunger risk. Ensuring food security is a decisive step towards achieving zero hunger. In the strategic layout of future mountain agriculture, the government should encourage large-scale food production in mountainous regions with lower altitudes and slopes, which are amenable to mechanized production. This would ensure that the 1.4 billion population has an adequate food supply. Simultaneously, the share of specialty agriculture should be expanded in areas with slightly higher altitudes and slopes. In addition to reducing the phenomenon of arable land abandonment, this approach can cultivate a range of small-scale, specialized, high-quality specialty agriculture, thereby easing the competition for land between grain production and specialty agriculture.

4.3. Improving the structure of specialty agriculture in mountainous areas

The promotion of rural revitalization has stimulated the emergence of muti-industry integration as a new approach to the development of specialty agriculture. However, it is clear that current specialty agriculture in China's mountainous areas is still largely at a rudimentary stage of development [48]. Traditional agriculture methods, including basic planting and breeding still occupy an important position, accounting for about 92.9% of the total number of OVOP-DVTs. In recent years, burgeoning reforms in rural areas, coupled with society's aspiration for improved living standards, have catalyzed the rapid growth of innovative agricultural ventures. Despite this development, the aggregate quantity and proportion of these ventures remain relatively insubstantial, representing a mere 2.5% of the total.

The restructuring and refinement of specialty agricultural frameworks should take precedence in future government agendas. This should not be limited to harmonizing traditional agricultural practices with emerging non-agricultural sectors through the establishment of smart agricultural tourism parks and e-commerce agricultural parks. Governments at all levels also bear the responsibility to further amplify coordinated planning and promotion of novel forms of specialty agriculture. The construction of robust platforms for specialty agriculture can help expand the horizons for comprehensive development in this field [33]. Moreover, it has the potential to create an array of diverse and superior employment opportunities for farmers, thereby contributing to income diversification. It is essential to consider such comprehensive approaches to ensure a sustainable and prosperous future for rural societies.

4.4. Research shortcomings and outlook

This paper provides a preliminary survey of the spatial distribution of specialty agriculture in mountainous areas. However, reliance on a single source of data, coupled with the fact that there are few surveys specific to specialty agriculture in China's mountainous regions, hinders the provision of a quantitative assessment of their sustainable development goals and hierarchical capabilities. Furthermore, while this paper has analyzed the existing supply of mountain specialty agriculture, it has neglected to quantify the potential demand for specialty agriculture. In future research, the focus will shift to western China and peripheral areas close to cities, incorporating data from farmer surveys to elucidate strategies for optimizing spatial allocation and exploring ways to improve development standards while taking demand into account.

5. Conclusions

This study investigates OVOP-DVTs in China's mountainous areas, scrutinizing both their horizontal distribution traits and vertical distribution across varying altitudes and slopes. The ultimate aim is to establish a scientific basis for the subsequent spatial layout of specialty agriculture in China's mountainous areas and to inform decisions to achieve SDGs. The main conclusions are as follows.

Regarding composition, specialty planting emerges as the dominant activity across all regions, closely followed by specialty breeding. However, the proportion of specialty breeding trails is that of specialty planting.

In terms of horizontal distribution, specialty agriculture in China's mountainous areas has evolved into eight circles, all strategically positioned at the junctions of provincial administrative units. The spatial distribution of specialty agriculture also exhibits stark regional disparities. Using the "Hu Line" as a demarcating boundary, the specialty agriculture east of this line constitutes an impressive 92.6% of the total number of OVOP-DVTs within mountainous areas.

Significant variations in the distribution of mountain specialty agriculture are also evident across altitudinal gradients. Remarkably, with 60.5% of specialty agriculture are situated in low-altitude regions of <500 m. The representation of mountain specialty agriculture declines progressively with increasing altitude. In terms of gradient terrains, the third one exhibits the largest proportion (58%) of OVOP-DVTs in the mountainous areas. From a slope perspective, the study finds that specialty agriculture in China's mountainous areas primarily concentrates in areas with gentle slopes, specifically less than 8°. Finally, the study presents policy recommendations for the future development and arrangement of specialty agriculture in China. The government should build infrastructure in the western region in the future and support the establishment of small-scale specialty agriculture in higher and steeper elevations to ease competition for land from grain production and specialty agriculture. In addition, the government should create a strong agricultural platform to promote diversified employment opportunities. These measures aim to reduce poverty among farmers, promote sustainable agriculture and provide a blueprint for other developing world.

Author contribution statement

Zhenyu Huang: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Minghong Tan: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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