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AGRO-CLIMATIC REGIONALIZATION OF KERNEL APRICOT (*PRUNUS ARMENIACA* × *SIBIRICA*) PLANTATIONS IN BEIJING

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Abstract

This study envisaged the distribution of the kernel apricot producing areas in Beijing using GIS technology, based on the climatic and geographical data of Beijing. The kernel apricot cultivation areas in Beijing area were classified as the most suitable area, suitable area, general suitable area, unsuitable area and least suitable area. The results indicated that the plains, hills, shallow mountains and valley basins of Beijing were the most suitable distribution areas of kernel apricot. The main cultivation places were in mountainous areas and shallow mountainous areas, and were classified under the suitable areas and general suitable areas of kernel apricot cultivation. At present, the planting area of kernel apricot in Beijing was 8346 hectares, which is the third largest economic forest tree species. It was found that the main production areas of kernel apricot included the Yanqing producing areas, Western Mountain producing areas and the northern mountain producing areas, accounting for more than four fifths of the cultivated area of kernel apricot in the city.

Introduction

Kernel apricot (*Prunus armeniaca* × *sibirica*) is an important woody grain and oil species originated in China (Zhang *et al*. 2011, O'Connell 2022, Saridas *et al*. 2024). It has strong cold resistance and drought resistance, and can be used to make products such as almond oil, almond dew, almond cream, etc. Developing kernel apricot planting can not only conserve the water and soil and afforest barren hills and slopes, but also yield economic benefits by almond processing and sale. It is one of the main economic forests of "Three North Shelterbelt" in China (Hou *et al*. 2008). Since 2000, a vigorous plantation of kernel apricot was carried in mountainous areas and shallow mountainous areas of Yanqing District, Huairou District, Mentougou District, and other places in Beijing, driven by the policy of "Grain for Green Project" (Lu *et al*. 2021). Kernel apricot is one of the most planted economic forests in Beijing, and the cultivated area accounts for more than 12% of the total economic forest area in the city. In recent years, the planting area of kernel apricot has shrunk from 11267 hectares a few years ago to 8346 hectares currently, which has had a negative impact on the development of agriculture in mountainous areas (Zhang and Cheng 2014). In this study, the precisional agro-climatic zoning of kernel apricot planting was performed based on GIS (Geographical Information System) technology, which can lead to an in-depth understanding of the present situation and existing problems of the kernel apricot planting in Beijing, and put forward scientific and reasonable suggestions to the development of local kernel apricot industry.

Materials and Methods

This study is mainly based on the climatic and geographical information of kernel apricot plantations by agro-climatic zoning using GIS technology. The climatic data was procured from the Beijing Meteorological Bureau, including the meteorological data, such as average monthly temperature, maximum monthly high temperature, monthly minimum temperature, annual

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accumulated temperature, monthly rainfall, monthly relative humidity and monthly sunshine hours from16 basic meteorological stations in the city from 1985 to 2015. Using the interpolation method and inversion algorithm of the National Meteorological Administration and the data of the National Basic Geographic Information Center (NGCC) (Yue *et al*. 2013, Zhu *et al*. 2023), the difference in the climatic data was transformed into spatial grid data with a resolution of 0.1 × 0.1 km, and a high-resolution climate factor meteorological map of the conventional data set of 0.1 × 0.1 km in Beijing area was developed. The data of National Basic Geographic Information Center mainly includes terrain data, digital elevation data and place name data in 2020, with a scale of 1: 250,000. The map making and data processing was accomplished by using ArcGIS 10.0 and Microsoft Excel software (Tang and Yang 2017, Li *et al*. 2018).

From 2017 to 2019, we conducted field visits and questionnaire surveys to investigate the cultivation status of kernel apricots in various districts of Beijing, including orchard area, growth, yield and quality, and production efficiency, studying the changes in the climatic conditions in its main producing areas. And repeated discussions were conducted with relevant experts on the main climatic factors affecting the growth of kernel apricot in Beijing, as well as the suitable range of these factors. The key factors of climate adaptation of kernel apricot were screened out and their range values were determined (Cheng *et al.* 2001, Zhang *et al*. 2019). Subsequently, the evaluation index system and scoring standard of climate factors of kernel apricot in Beijing were established (Han 2010, Li *et al*. 2015). By means of expert scoring model evaluation, the possible suitable cultivation areas were divided into five grades: the most suitable cultivation area, the suitable cultivation area, the general suitable cultivation area, the unsuitable cultivation area and the least suitable cultivation area through spatial operation and grading treatment. Combined with the big data of the kernel apricot production survey in 2020 (Zhang and Jie 2022), this study analyzed its distribution and puts forward targeted suggestions.

Results and Discussion

Kernel apricot is one of the economic forest tree species with the largest planting area in Beijing. By 2020, the planting area of kernel apricot in the city was 8346 hectares, which is the third largest economic forest tree species with the planting area, accounting for 12.14% of all economic forests in Beijing. It is mainly distributed in Yanqing, Mentougou, Huairou, Fangshan and Miyun District (Table 1). In 2020, the yield of kernel apricots in the whole city was 5358.8 tons, in which Yanqing District produced the highest yield of 3749.7 tons, accounting for 70.0% of the total output of the whole city. In 2020, the output value of kernel apricot processing was 6.08 million $, accounting for 1.15% of the total output value of fruits in the city, in which Yanqing District conferred the highest output value of 4.35 million $, accounting for 72.38% of the total output value of kernel apricot for kernel use in the city (Table 1).

Among the kernel apricot varieties cultivated in Beijing, “Longwangmao” is the most cultivated variety, followed by “You1” in 2020. The varieties selected locally in Beijing exhibited a strong adaptability to climate, but are greatly affected by late frost and frequent frozen flowers. It can be seen from Fig. 1 that the 16-20 years old kernel apricot use accounts for the largest proportion, accounting for 60% of all ages, which is mainly affected by the policy of “Grain for Green Project” from 2000 to 2005. Due to the change of policy and low price (Li 2020), the enthusiasm for planting kernel apricots use has plummeted in recent years. In the future, the production of kernel apricots in Beijing should focus on the existing stock management, and should not be developed in a large area.

Kernel apricot is a particularly cold-resistant economic forest tree species, which grows in areas with an average annual temperature of 4.0~16.0℃ and a frost-free period of more than 120 days, and can endure extreme low temperature of -31. 5℃ in winter dormant period (Cheng *et al.* 2001, Li *et al.* 2015). It is also a high temperature resistant tree species, with the highest temperature of 43℃, where it can still grow and bear fruits normally. Apricots blooms early, and its flowers and young fruits are very sensitive to low temperature (Yang *et al.* 2006b, Khadivi and Hossseini 2024). Low temperature of -2℃ can freeze flower organs, 0℃ can frostbite the young fruits, and late frost is frequent in Beijing, which is the main natural disaster affecting the fruit setting. Rain, cold and early wind in flowering period affects the pollination of the insects, resulting in poor pollination and sharp drop in yield. Kernel apricot trees have strong drought resistance and can grow and bear fruit normally in the area with an annual precipitation of 350 ~ 800 mm. However, apricot trees are not resistant to water and humidity, water accumulation in apricot orchard for 3 days leads to yellow leaves, dead roots and even death of the whole plant.

Table 1. Distribution of kernel apricot planting area, yield and output value in Beijing.

	Planting area		Yield		Output	
	Value (ha)	Percent (%)	Value(t)	Percent (%)	Value ($)	Percent (%)
Yanqing district	4640	55.59	3749.7	70.0	4348991	72.38
Mentougou District	1888	22.62	1055.2	19.7	710595	11.83
Huairou District	852	10.2	173.9	3.2	331695	5.52
Fangshan District	589	7.06	34	0.6	88437	1.47
Miyun District	282	3.37	339	6.3	501044	8.34
Other Districts	96	1.15	7	0.2	27691	0.46

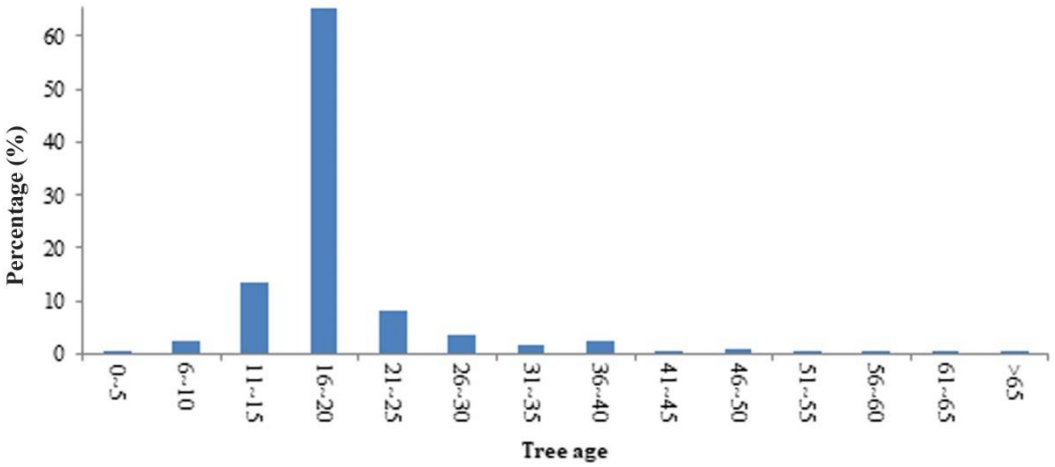

Fig. 1. Age distribution (years) map of kernel apricot in Beijing.

Considering the actual production of kernel apricot in Beijing, seven indexes such as average annual temperature, average highest temperature from June to September, frost-free period, sunshine hours, altitude, slope gradient, and annual precipitation were determined as the zoning

factors, and the relevant standards can be seen in Table 2. From the analysis, the comprehensive evaluation values were divided into five grades: most suitable, suitable, generally suitable, unsuitable and least suitable. It can be seen from Fig. 2 that the suitable producing areas of kernel apricot in Beijing were wide, and it is the largest tree species in the suitable area among the main economic forests in Beijing. The most suitable producing areas were mainly distributed in the piedmont gentle land and plain area in the central and western part of Beijing, and in the eastern plain area. There was also a small area suitable for kernel apricot cultivation in Miyun Valley Basin, and there were also some suitable producing areas in Yanqing Valley. Because of the low temperature and thin soil layer in high altitude mountainous areas of Beijing, it is not conducive to the production of kernel apricot. However, the low altitude areas such as Yongding River and Dashi River were found to be a suitable area for kernel apricot.

Table 2. Zonation indicators and scoring criteria for kernel apricot in Beijing.

Zonation indicator	Criteria	Persimmon score
Average annual temperature /℃	>8	30
	6.1~8	20
	5.1~6	15
	<4.1~5	5
	<=4	0
Average highest temperature from June to September /℃	>28	5
	26.1~28	10
	24.1~26	15
	<=24	5
Frost-free period/d	>165	20
	140.1~165	10
	120.1~140	5
	<=120	0
Sunshine hours/hr	>2500	15
	2200.1~2500	10
	1800.1~2200	5
	<=1800	0
Altitude/m	0~200	5
	200.1~600	15
	600.1~1000	10
	>1000	0
Slope gradient	0~6	15
	6.1~15	10
	15.1~25	5
	>25	0
Annual precipitation /mm	>650	15
	450.1~650	20
	350.1~450	10
	<=350	0

It can be seen from Fig. 2 that the area suitable for cultivation of kernel apricot in Beijing is very large, mainly because the environmental adaptability of the kernel apricot is extremely strong. The Longwangmao variety cultivated in Beijing was selected in Mentougou mountainous area, so it was suitable for planting kernel apricots in Beijing, except the mountainous areas with extremely high altitude. Plains, hills, shallow mountains and valley basins in Beijing were the most suitable distribution areas for kernel apricots.

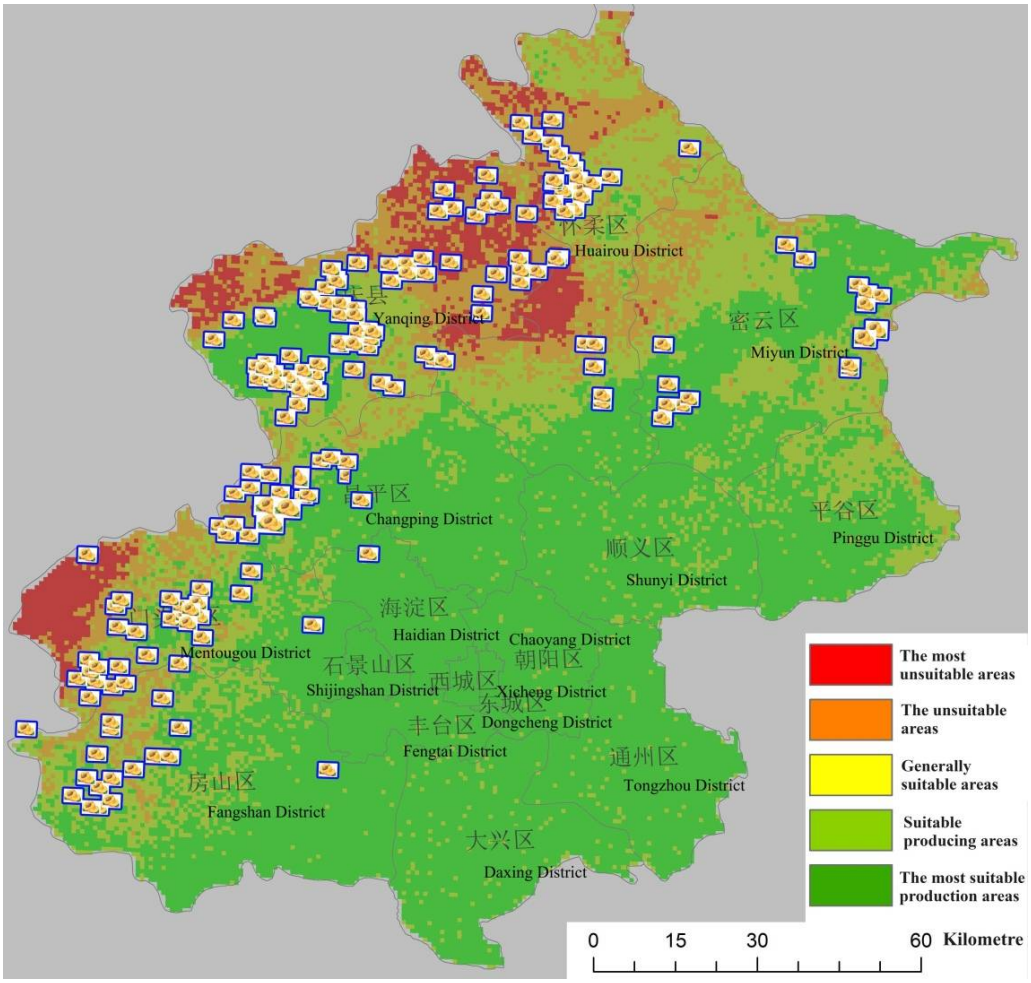

Fig. 2. Distribution of suitable producing areas of kernel apricot in Beijing.

The most suitable producing areas mainly included the central city, the central and eastern plains, the southern and southwestern plains, the piedmont slow land in the northern and western plains, and the valley basin in Yanqing. The area of this production area accounted for about two-third of the total area of the city, but it was mainly distributed in urban areas, crops and fruits, etc., and the actual cultivation of apricot noodles for kernels was active and less. The altitude of this production area was generally below 300 meters, the average annual temperature was above 8°C, the frost-free period was above 185 days, and the average annual rainfall was mostly 550-600mm.

Suitable producing areas mainly included the shallow mountainous areas in the west and north, hilly areas in the east, and some river valleys with higher altitudes in Miyun, Huairou and Yanqing. Most of this area belonged to shallow mountains, river valleys or hilly areas, which was the main area for cultivating kernel apricots. The altitude of this production area was generally about 300-600 meters, the average annual temperature was 8-10°C, the frost-free period was 160-185 days, and the rainfall was about 600 mm.

Generally, the suitable producing areas were located in the high-altitude areas in the west, north or northeast of the suitable areas, including some high altitude basins in Yanqing (600-1000 meters), the average annual temperature was mostly 6-8°C, and the rainfall was generally 500-600 mm. Some places were affected by microclimate, and the rainfall exceeded 600 mm. This area was one of the main cultivation areas of kernel apricot, especially in the mountainous areas of Yanqing, where many kernel apricot plantations have been developed under the original policy of "Grain for Green Project".

The unsuitable production areas were mainly the mountainous areas higher than 1000 meters, and the areas with average annual temperature generally less than 6°C. In this area, the altitude was high, the soil layer was thin, and the management was inconvenient, leading to a low cultivation.

The most unsuitable areas were mainly the high mountain areas higher than 1200 meters, with thin soil layer and steep terrain, with an average annual temperature less than 6°C. There was basically no kernel apricot cultivation in these high areas.

Most of the kernel apricots in Beijing are developed under the policy of "Grain for Green Project" (Yang *et al*. 2006a). Kernel apricots belong to economic forests, which are based on the development principle of "going up the mountain and going down the beach". As a result, the main cultivation places are in mountainous areas and shallow mountainous areas, and most of them belong to suitable areas and general suitable areas of cultivation. Although the most suitable area for kernel apricot cultivation was mainly in plain, due to the policy of "not competing with grain for land", kernel apricot planting in Beijing was mainly distributed in the shallow mountainous areas, hilly areas, slow areas in front of mountains, and mountain valley basins, most of which were distributed in the western mountainous areas, which can be roughly divided into three producing areas as follows:

Yanqing producing areas is mainly located in the valley basin of Yanqing District and the northwest mountainous area, of which Qianjiadian Town has the largest area, accounting for 11.53% of the total area of kernel apricot in the city. It is followed by Zhangshanying Town, accounting for 4.85% of the city, Jingzhuang Town (4.15%), Jiuxian Town (3.92%), Xiangying Town (3.91%), Kangzhuang Town (3.16%), Dayushu Town (3.07%), Badaling Town (2.72%) and Yongning Town (2.60%).

The western mountain producing areas are mainly Fangshan, Mentougou and shallow mountainous areas or valleys in the west of Changping. The main towns include Qingshui Town in Mentougou, accounting for 7.9% of the total area of kernel apricots in the city. Zhaitang Town (6.32%) and Yanchi Town (3.50%) in Mentougou District also have several kernel apricot plantations. The production area also includes Shidu Town (2.85%) and Xiayunling Town (2.81%) in Fangshan District, and Liucun Town (5.66%) in Changping District.

The northern mountain producing areas mainly include Huairou and Miyun shallow mountainous areas, and the key producing towns are Baoshan Town in Huairou and Xitian Gezhuang Town in Miyun District. The planting area of kernel apricot accounts for 6.99 and 3.55% of the whole city, respectively.

Other producing areas are mainly individual areas of Pinggu District, Changping District and Shunyi District shallow mountains.

Kernel apricot is the third largest dried fruit in Beijing. The output value of kernel apricot is 6.08 million $, accounting for 1.15% of the total fruit income. At present, the plantation area of kernel apricot in Beijing has decreased sharply which was mainly due to the change of policy. The vigorous development in that year was mainly affected by the policy of "Grain for Green Project" (Lu *et al*. 2021), and currently it is mainly affected by the policy of "Returning Forest to Farming".

In addition, kernel apricots were mainly distributed in mountainous areas, which are not driven by processing enterprises. There are many problems, such as poor water and fertilizer conditions, low yield, low benefit and older practitioners. For example, Yanqing District accounts for 81.5% of the output value of kernel apricots per hectare less than 1087 $. The income per hectare is 1087 ~ 2175 $, accounting for 13.28%. Only 5.22% of the income per hectare is more than 2175 $. Among the growers of kernel apricot in Yanqing District, the proportion of primary school and junior high school education is 90.31%, and an average age of 59.5 years.

At present, under the policy of "Returning Forests to Farming" in Beijing (Zhou *et al*. 2024), the number of kernel apricot orchards for kernel use is decreasing and the price is low, which proves that the development of kernel apricot fruit industry for kernel use in Beijing can only take the road of transformation and development. There is a need to pay an attention to the quality and efficiency, without pursuing area and quantity expansion. In the process of development, the leading processing enterprises should drive and upgrade the modernization level of fruit trees as the main line, and possess a fundamental purpose to increase the income of fruit farmers. By innovating mode and strengthening management, the sharply shrinking kernel apricot industry in Beijing can be quickly bloomed. The recommendations are as follows:

Introduce leading enterprises to enlarge and strengthen the kernel apricot processing industry: The fresh consumption of apricot kernel is very rare and the price is low, while traditional dried apricot is mainly made in Beijing that has low price and small market capacity. There is a lack of kernel apricot processing enterprises in the local area, and the industrialization level of kernel apricot processing is low (Li 2010). The development of secondary production drives primary production; in this pursuit, introducing kernel apricot processing enterprises can continuously extend the industrial chain by developing secondary almond processing products, such as almond dew and almond oil, and continuously tap its potential economic value.

Innovative mode, integration of industries: Currently, the family-oriented small-scale business is the main body of kernel apricot production in Beijing. There is a need to strengthen sightseeing and picking, establish citizen orchards, develop leisure tourism and health care, which can give full play to the advantages of Beijing as an international metropolis, and increase income through business diversification (Zhang *et al*. 2022).

Establishment of specialized service companies: There is a need to provide specialized services such as the introduction of fertilizers, pruning, pesticide spraying and sales-services to the fruit farmers through specialized companies or cooperatives. This can improve efficiency and orchard modernization to a significant extent. At present, most cooperatives in Beijing are loose structures, which fail to provide effective services to fruit farmers, and this aspect needs active guidance (Zhang *et al*. 2017).

Reducing labor input: At present, the labor cost in Beijing is accounted for more than half of the production cost of kernel apricot use. Reducing the labor cost is the fastest and most direct way to increase the income, which is mainly realized through the application of water and

fertilizer integration, green plant protection methods, simplified pruning, orchard machinery and other technologies (Liu *et al*. 2015).

Introducing social capital and expanding financing channels: Under the guidance of Fruit Tree Industry Development Fund, there is a need to actively attract social capital investment and promote industrial upgrading through capital operation. In particular, fruit processing, e-commerce and kernel apricot production should be integrated (Zhang and Cheng 2014), so as to continuously broaden the financing channels and reduce financing costs.

Need to publicity: There is a need for the publicity and construction of the kernel apricot brand to enhance the brand value of kernel apricot. Instead of employing the traditional sales methods and channels, the marketing mode should be innovated, the nutritional value of kernel apricot use should be widely publicized, and the competitiveness of the main producing areas of kernel apricot use should be improved by holding processing experience and tourism culture festival activities.

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