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# AGROCLIMATIC ZONING OF FRESH FRUIT GROWING AREAS IN BEIJING USING GIS TECHNOLOGY

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*Keywords:* Agroclimatic zoning, Fresh Fruit, Beijing, GIS

## Abstract

Beijing has a fresh fruit tree cultivation area of 70.7 thousand hectares, accounting for 51.96% of the total fruit tree planting area. Though it involves a total of 159,000 households, the income per household is only 24225 yuan. By collecting the basic data regarding climate, ecology, and soil, and correlating them with the climatic and ecological adaptabilities of the crops, a fine zonation for each of the four most important fresh fruits produced in Beijing (100 m × 100 m) using GIS technology was developed. Each zonation identified the most suitable, fairly suitable, suitable, unsuitable and the most unsuitable. Providing a theoretical basis for the optimal layout of fresh fruit production facilities, ideal producing areas for the main fresh fruits industries was suggested.

## Introduction

In 2015, the planting area of fruit trees was 136 thousand hectares in Beijing, of which the growing area of fresh fruits was 70.7 thousand hectares. The output value of fresh fruits was 3.851 billion RMB, accounting for 88.8% of total revenue of fruits. The growing area of peach trees was 20.9 thousand hectares that was the largest amongst the growing area of all the fruit trees. Other major fresh fruits included apples (8,400 ha), pears (7,600 ha) and grapes (2,900 ha). Beijing does not only possess a huge consumer market, but also favorable ecological conditions for the growth of deciduous fruit trees. However, the overall level of production of fruit trees remains low and many problems are still left unsolved. The development of fruit tree industry varies significantly across different districts and counties in Beijing, and so does the managerial level of the orchards. This results in a significant variation in the development level and the benefits of the regional fruit tree industry. Moreover, along with the accelerating urbanization in Beijing, the planting area of fruit trees has shown a decreasing trend, which threatens the sustainable and stable development of Beijing's fruit tree industry. In this study, an agroclimatic zoning of four fruit tree species, based on the climatic and ecological conditions in Beijing was done (Chen and Huang 1988, Han 2010). The research findings shed new light on the need of optimization and modernization of the plantation of the fruit trees in Beijing.

## Materials and Methods

The mapping tools ArcGIS 10.210 and ENVI5.2 (Esri) were used for data processing and analysis. Climate data mainly consisted of meteorological data at the weather stations in Beijing and all districts and counties surrounding Beijing. The meteorological data dated from 1985 to 2015 were collected from 16 representative weather stations. The data covered the following aspects: thermal resource elements (annual average temperature, monthly average temperature from April to October, warmth index, average temperature of January, average maximum temperature from July

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to August, annual accumulated temperature), light resource elements (annual sunshine duration), and water resource elements (annual precipitation and average precipitation from April to October). Other relevant data included the basic Geographic Information System (GIS) data and soil data (soil thickness, texture, and pH value) of the study area. Basic GIS data including topography, digital elevation data, and place names on a scale of 1 : 250000 were provided by the National Geomatics Center of China (NGCC).

Small grid calculation model was established for different zoning indicators. Multiple stepwise regression was used to model the relationship between each of the climatic element, latitude, longitude, and altitude. Thus the small grid calculation model for each climatic element for different fruit tree species was constructed (Cai *et al.* 2005). Initially, the raster digital elevation model (DEM) data were converted into the point data, and the X and Y coordinates of each point were extracted from the DEM data as the longitude and latitude, respectively. The point elements were converted back to a raster format for the subsequent small grid calculation. Subsequently, using the above-mentioned small grid calculation models for different zoning indicators and raster calculator in ArcGIS 10.0 2, the values of each zoning indicator were calculated (Tang *et al*. 2017). The results showed the actual spatial distribution of each zoning indicator, which provided an intuitive picture of the 3D variation features of the zoning indicator with the geographical position and altitude. The altitude of each point was extracted to generate the point layer. Then ArcGIS10.2 was used to extract the slope and aspect data and to generate the thematic maps of slope and aspect. The raster meteorological data were generated for different topographic features using the small grid calculation models for each climatic element. The spatial interpolation tool based on the Bayesian network in ArcGIS10.2 was adopted to generate the spatial distribution map of each climatic element.

The scoring system for agroclimatic zoning of different fruit tree species was established. Using the ENVI5.2 application and decision tree for classification, the raster data of each assessment indicator were reclassified according to the scoring system. The raster DN values were assigned specific scores according to their grades, and the new classified raster maps were generated based on the generated scores. The meteorological, topographic and soil data were reclassified based on the scores. The mapping tool of ArcGIS10.2 was utilized to overlay the raster maps of the final scores onto the administrative division map. Five grades were set up according to the scores using different colors. The map elements were added, if necessary, to generate the agroclimatic zoning maps for the different fruit tree species.

**Results and Discussion**

Beijing, a mid-latitude city, is located on the east bank of the East Asian Continent and possesses a continental monsoon climate. The winter weather, governed by high atmospheric pressure from Mongolia, is dry. The spring is windy, the summer is rainy and the autumn is usually sunny and temperate. Beijing is surrounded by mountains on its east, west, and north. In winter, the movement of northwest cold air is impeded by the high mountains. The subsiding cold air produces a warming effect. Hence, Beijing is warmer than other regions of the same latitude. In summer, the southeast warm and humid air current get regulated by the ocean, which helps to reduce the air temperature. On the whole, Beijing is located in the cold temperate zone. The plain areas belongs to the warm temperate zone and semi-humid zone, while the mountainous regions of Yanqing, Mentougou, and Huairou are located in the transition zone, from temperate and semi-humid climate to semi-arid climate. Distinct microclimates are usually found in areas surrounded by mountains and forests.

Temperature is a limiting factor in the distribution of fruit trees. The boundaries of the distribution of fruit trees are mainly determined by the annual average temperature as well as the minimum and maximum temperature distribution. It is known that the temperature distribution plays a decisive role in the fruit quality. The annual average temperature is 11.8ºC in Beijing. As shown in Fig. 1, the annual average temperature was lower in the west and north of Beijing, but higher in the middle, south, and east of Beijing. Considering the limited area of Beijing, such variability of temperature is mainly caused by the difference in altitude. Generally, for every increase of altitude by 1000 m, the temperature decreases by 6ºC. As the altitude increases, the temperature gradually decreases from the plain area to the mountainous regions in the northwest. The temperature of the piedmont plain was higher, with an annual average temperature of 11-13ºC. The annual average temperature of the Yanqing Basin was 8ºC. The annual average temperature of the Ling mountain in the Mentougou and Dahaituo mountains in Yanqing was surprisingly only 2ºC. Common deciduous fruit trees are cultivated in the plain and shallow mountainous areas of Beijing. Ussurian pear, plum, and northern peach can be cultivated in the basin and shallow mountainous areas at an altitude below 500 m. The months of stable growth and highest accumulation of photosynthetic products in these fruit trees were found to be from June to September. A high temperature during this period can have a direct impact on the accumulation of photosynthetic products and fruit quality. The number of days with temperature above 30ºC exceeds 60 in the central urban area, and 55 in the plain area (Fig. 2). However, the long duration of high temperature in these regions is unfavorable in the formation of the fruit quality, especially for apples and grapes. However, the pear and peach trees are not so sensitive to higher temperatures.

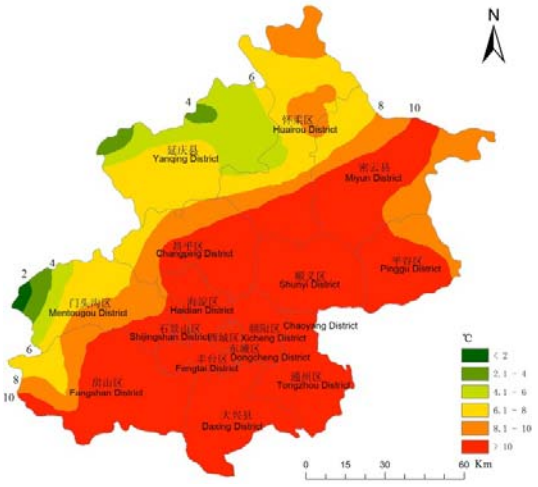


Fig. 1. Distribution of the annual average temperature of Beijing.

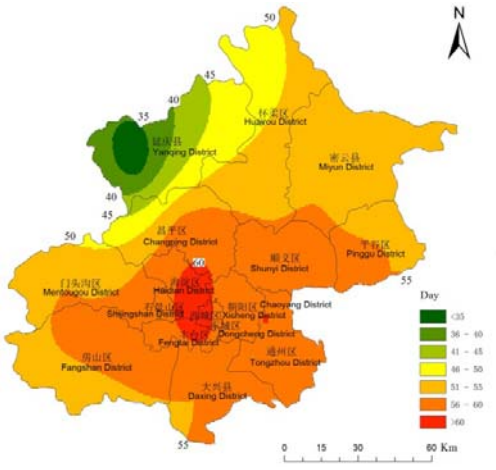


Fig. 2. Distribution of the number of days with tempera-ture above 30ºC from June to September in Beijing.

The precipitation distribution of Beijing is shown in Fig. 3. Variability of the precipitation is mainly related to the relative position of mountains. Windward slopes are usually regions of higher precipitation, while the leeward slopes have a much lower precipitation. The southeast part of Beijing is located in the plain area with a low altitude and exhibited an annual average precipitation of only ~600 mm. The Yanqing basin and Qingshui river valley in Zhaitang, Mentougou are located in the slopes leeward of the summer monsoon, where the precipitation is low, with the annual average precipitation less than 500 mm. The windward slopes tend to have a much larger

precipitation, such as the Badaohe region in Huairou, Manshui river in Fangshan, Jiangjunguan in Pinggu and Fuozizhuang in Fangshan. In these regions, the annual average precipitation exceeds 700 mm.

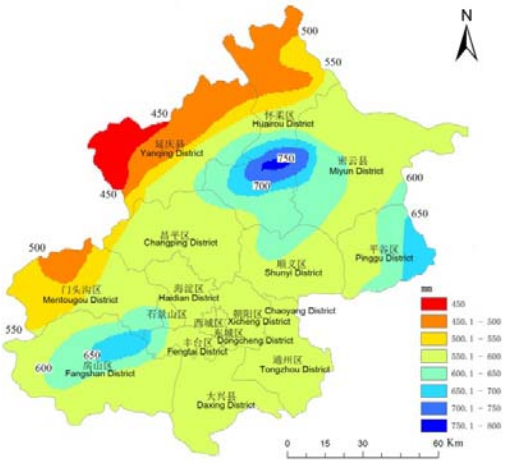


Fig. 3. In Beijing over the yeas distribution of annual average precipitation.

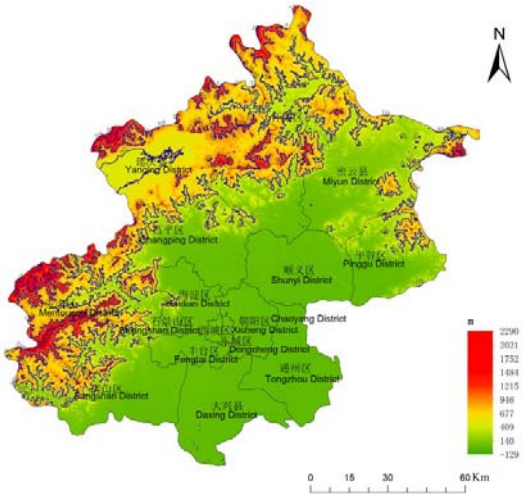


Fig. 4. Altitude distribution map of Beijing.

The altitude varies inversely with temperature. A low temperature restricts the cultivation of many fruit tree species. Moreover, higher the altitude, the greater the temperature difference between the day and night and better is the fruit quality. Therefore, the piedmont warm zones, shallow mountainous areas, and the vasin valleys are the best growing areas for the fruit trees. The altitude distribution of different parts of Beijing is shown in Fig. 4. Beijing is a mid-latitude city, and the areas above 500 m altitude are not suitable for the growing fruit trees. Moreover, the slopes are steeper where the altitude varied significantly. Generally, a slope gradient below 5° is best for growing fruit trees.

In North China, the average annual temperature, most suitable for the growth of peach trees is 8-14ºC, and the lowest temperature in winter is above –23ºC (Wang *et al*. 1984, Li 1984). Different combinations and seasonal (inter-annual) changes of environmental factors such as sunlight, water, and soil produce a significant impact on the growth of peach trees and fruit quality. Screening and optimization for the cultivation of the best-grown peach tree varieties under regional climate and soil conditions are the key steps in producing high-quality peaches. The main indicators for agroclimatic zoning of peach trees were determined based on field surveys (Wang 1984, Wang *et al*. 1984), and the scoring criteria are shown in Table 1. Amongst all indicators for agroclimatic zoning, the annual average temperature was found to be the most important factor in determining the degree of suitability for growing peach trees.

Furthermore, the number of days with high temperature in summer was another influencing factor for the fruit yield and quality. Altitude usually influences the Brix value and sensory quality of fruits. Within a certain range, the higher the altitude, the higher is the Brix value. Precipitation is also an important climatic factor during the maturity period of fruits. Too much precipitation may lead to fruit drop and cracking, and insufficient precipitation can impede the fruit growth.

**Table 1. Indicators and scoring criteria for agroclimatic zoning of fresh fruits.**

| Zoning indicators | Range | Apple | Sand pear | White pear | Peach | Grape |
|---|---|---|---|---|---|---|
| Annual average temperature/ºC | >=11.5 | 35 | 40 | 30 | 30 | 25 |
| | 9 ~ 11.5 | 40 | 25 | 25 | 25 | 20 |
| | 7 ~ 9 | 30 | 15 | 15 | 15 | 10 |
| | 6 ~ 7 | 20 | 5 | 5 | 5 | 5 |
| | <6.5 | 0 | 0 | 0 | 0 | 0 |
| Average temperature in January/ºC | >-6 | 15 | 15 | 15 | 15 | 15 |
| | –6 ~ -8 | 10 | 10 | 10 | 10 | 10 |
| | –8 ~ -10 | 5 | 5 | 5 | 5 | 5 |
| | <-10 | 0 | -10 | 0 | 0 | 0 |
| Number of days above 30ºC from June to August/d | | 15 | -- | -- | 10 | 15 |
| | | 10 | -- | -- | 8 | 10 |
| | | 5 | -- | -- | 5 | 5 |
| | | 0 | -- | -- | 0 | 0 |
| Altitude (m) | 0 ~ 60 | 10 | 15 | 5 | 5 | 10 |
| | 60 ~ 300 | 15 | 10 | 15 | 15 | 15 |
| | 300 ~ 600 | 5 | 10 | 10 | 10 | 10 |
| | = 600 | 0 | 0 | 0 | 0 | 0 |
| Slope gradient | 0 ~ 6 | 15 | 20 | 20 | 20 | 10 |
| | 6 ~ 12 | 10 | 10 | 10 | 10 | 10 |
| | 14 ~ 20 | 5 | 5 | 5 | 5 | 5 |
| | >20 | –10 | –10 | –10 | 0 | 0 |
| Annual precipitation (mm) | >700 | 15 | 30 | 30 | 30 | 15 |
| | 600 ~ 700 | 10 | 25 | 25 | 25 | 15 |
| | 500 ~ 600 | 5 | 20 | 20 | 20 | 10 |
| | <=500 | 5 | 5 | 5 | 5 | 5 |
| Soil texture | Clayey soil | 5 | 0 | 0 | 0 | 5 |
| | Loamy soil | 12 | 15 | 15 | 15 | 12 |
| | Sandy loam | 15 | 20 | 20 | 10 | 15 |
| | Sandy soil | 2 | 15 | 15 | 5 | 2 |

After the mapping of zoning indicators, expert scoring was performed according to the range used for the indicators. The raster layer for the assessment of a single factor was generated. Using the overlaying tool in GIS, the raster layers for different factors were superimposed together to obtain the overall raster layer. Many regions in Beijing are suitable for growing peach trees, especially the plain areas and shallow mountainous areas Fig. 5. Peach is native to North China and is adaptive to the ecological conditions of Beijing. Various terrains like the plain, hills, shallow mountains and river basins are suitable for the growth of peach trees. However, high-altitude regions are not suitable, and peach trees can hardly be grown in regions above 1,200 m altitude.

Peach a fruit tree species is widely grown in Beijing. The total growing area of peach is 20.9 thousand hectares, accounting for 15.3% of the total growing area of fruit trees. The total annual revenue of peach trees is 1.67 billion yuan, accounting for 38.6% of total revenues of fruits (Table 2). Intensive development will be the favored pathway of development by increasing the existing growing area of peach trees and enhancing the fruit quality. The growing area of peach trees in Pinggu totals to 13.3 thousand hectares, thus accounting 65% of the total growing area of peach trees in Beijing. Pinggu does not only possess favorable ecological conditions, but the advanced

production and managerial system make this district the most suitable growing area for peach trees. Other districts can learn from the experience of Pinggu, as the areas suitable for growing peach trees are extensive and the cultivation skills of peach trees are easy to master. The biggest challenge facing the peach tree industry is the low price of peaches in the market. An increase in the labor cost and agricultural materials result in low economic benefits in growing peach trees.

**Table 2. The growing area and total revenues of main fruit tree in Beijing.**

| | Total Fruit | Apple | Pear | Peach | Grape | Others |
|---|---|---|---|---|---|---|
| Area ($10^3$ Ha) | 135.89 | 8.41 | 7.59 | 20.86 | 2.95 | 96.08 |
| Total revenues($10^6$ yuan) | 4339.00 | 622.12 | 506.79 | 1673.46 | 315.29 | 1221.34 |

Apple trees are native to temperate zones and can tolerate low temperature and dry climate. The winter should not be severely cold and the summer should not be intensely hot in the areas suitable for growing apple trees. The suitable range of annual average temperature is 9 - 14ºC, with the minimum temperature in winter not below –12ºC, and the monthly average temperature in summer should not be above 20ºC. The average temperature is below 7.5ºC in the west and mountainous areas in the north of Beijing, whereas the average temperatures in all other districts of Beijing are within this range (Fig. 1). The high temperature in summer i.e., average temperature above 26ºC can lead to the poor flower bud differentiation. The 540mm precipitation is sufficient for the growth of apple trees. Soil exhibits a significant impact on the growth, yield, and quality of apples. In this study, the influence of soil texture was mainly considered. Generally, the higher the altitude, the lower the temperature and larger is the temperature difference. An altitude of 650 - 1400 m is conducive to the fruit quality of apple trees. However, being a mid-latitude city, Beijing has a comparatively low annual average temperature. So a more flexible approach to choosing the appropriate altitude for growing apple trees is necessary. A large slope gradient will make the orchard management difficult. A terraced field is needed when the slope gradient is above 5 degrees, and apple trees can hardly grow under a slope gradient above 20 degrees. Regions with a higher slope gradient usually possess a thin soil layer, hence the slope gradient was included as an important indicator for the zoning. The zoning indicators and scoring criteria were determined for apple trees based on the above analysis (Table 1) (Li *et al*. 2013, Yin *et al*. 2014).

Comprehensive scores were allotted according to the current distribution of apple trees in Beijing. Five levels of suitability were set up, namely, most suitable, fairly suitable, suitable, unsuitable and most unsuitable.

It can be seen from Fig. 6 that the most suitable growing areas for apple trees were located at the boundary between the plain areas and mountainous regions, the river basins of the Miyun and Huairou, Yanqing, and on the banks of the Yongdinghe River in Mentougou. The areas favorable for growth areas were found in the periphery of the most suitable areas in the central urban district and the plains in the east. Unsuitable growing areas were usually the high-altitude mountainous regions, especially the mountainous areas in the west and northwest. Apple trees cannot thrive above an altitude of 1,000 m in Beijing. Some apple varieties such as Fuji apple are known to suffer from freeze injury if grown above 600 m altitude.

At present, the apple growing area in Beijing totals 8.4 thousand hectares (Table 2). The major apple-growing areas include the piedmont warm belts in the north, river valley in the mountainous areas in the northeast, Yanqing basin and mountainous areas in the Yanqing, banks of the Yongdinghe River in Mentougou, southwest of Beijing, and scattered plain areas in the south. Five major apple growing areas in the piedmont warm belts in the north will be the focus of development.

The growing areas need to be expanded in the suitable regions, and efforts should be directed to improve the fruit quality and construction of sightseeing orchard, so as to strengthen the apple tree industry. Based on the zoning results, an increase in the growing areas of apples by 1 - 2 thousand hectares in the future is recommended, so that the total growing area of apple trees will reach about 10 thousand hectares.

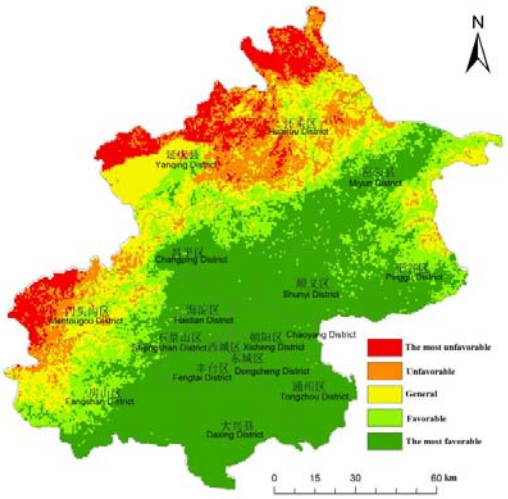


Fig. 5. Distribution of areas suitable for growing peach trees in Beijing.

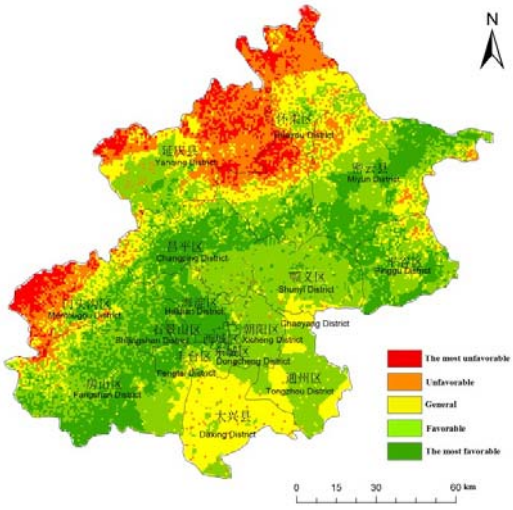


Fig. 6. Distribution of areas suitable for growing apple trees in Beijing.

Pear trees prefer a warm climate and their growth require a higher temperature, while a low temperature is favored during the dormancy. The appropriate range of annual average temperature for growing pear trees is about 7 - 15ºC, and about 13 - 21ºC for sand pears (Guo *et al*. 2010a,b). The growth of pear trees requires a higher amount of water compared with other fruit trees. An agroclimatic zoning of white pear and sand pear based on their requirements on environmental conditions were done. Ussurian pear has a similar environmental tolerance as that of the white pear (can better tolerate low temperature). European pear cannot be extensively grown in Beijing and therefore this species was not considered in this study. The assessment indicators and scoring criteria were formulated based on the above analysis (Table 1). Water content of soil is a key factor influencing the fruit quality during the fruit swelling period. If the water supply is low in spring, the fruit size can shrink considerably, thus impairing its commercial value. This fact was also considered in the zoning. The score of 20 was given to regions with sufficient water supply for sand pear, 15 to regions with moderate water supply, 5 to regions with mild water deficiency, and 0 to regions with severe water deficiency. The corresponding scores for white pear were 15, 10, 5 and 0, respectively. Comprehensive scores were given combining the distribution patterns of white pear and sand pear in Beijing. Based on these scores, five levels of suitability were set up, namely, most suitable, fairly suitable, suitable, unsuitable and most unsuitable area.

There exists an extensive area that is suitable for growing the white pear (Fig. 7). Except for high-altitude mountainous areas, other terrains like the plains, shallow mountains, and hills are suitable for the growth of white pears. Plain areas in the middle, south and east of Beijing are most suitable. In contrast, the mountainous areas in the west and north are not suitable due to low

temperature and thin soil layer. Sand pear has a higher requirement of temperature and water supply, and therefore the areas suitable for growing sand pear are smaller. The most suitable regions are generally found in low-altitude plain areas, while shallow mountains and the hills (Fig. 8). It should be noted that insufficient irrigation has an adverse impact on the pear size and quality. Therefore, it is not suitable to grow sand pear even in the ecologically suitable regions, if the irrigation does not meet the requirement. Ussurian pear has similar environmental requirements as white pear and can tolerate lower temperature compared to the white pear. The suitable regions for growing Ussurian pear are basically consistent with that of white pear. Ussurian pear can be grown in shallow mountains.

The growing area of pear trees is 7.6 thousand hectares in Beijing, accounting for 5.6% of the total growing area of fruit trees (Table 2). The distribution of pear trees is more concentrated in the five major growing areas, namely, the sandy land on the banks of Yongdinghe river in the south, the plains in the south of Daxing, the two banks of Chaobaihe River, the shallow mountains in the northeast, and the Western Hills. Pear trees are one of the traditional fruit tree species in Beijing, and thus the pear tree industry needs to be properly maintained and developed. The existing growing areas of pear trees should be maintained in plain areas, and new growing areas can be developed in mountainous areas, especially for the famous traditional varieties, such as Yali pear, Zimu pear, Jingbai pear and Hongxiao pear.

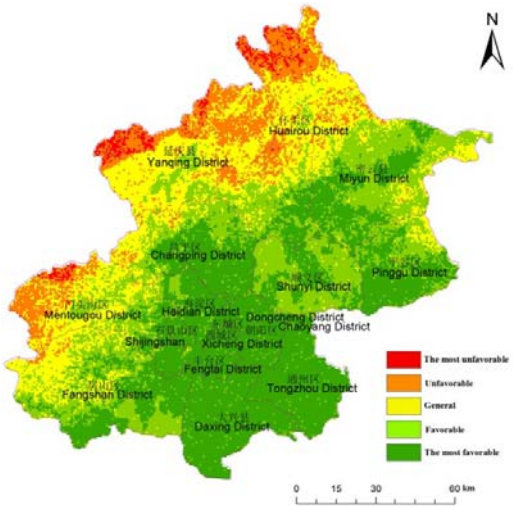


Fig. 7. Distribution of areas suitable for growing white pear trees in Beijing.

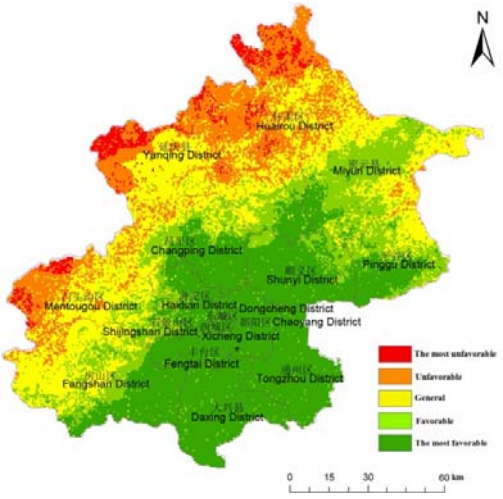


Fig. 8. Distribution of areas suitable for growing sand pear trees in Beijing.

Grapes originate from the temperature zones and prefer a warm climate. The average temperature required for the germination of European grapes is 10 - 12ºC, and that for flowering, shoot formation and flower bud differentiation is 25 - 30ºC. The most appropriate temperature for the maturity of grapes is 28 - 32ºC (Luo *et al*. 2001, Huang *et al*. 2000). The above ranges of temperature are most suitable for the glucose accumulation and decomposition of the organic acids. However, the high temperature in summer is not conducive to glucose accumulation and fruit quality formation. Grapes cannot tolerate low temperature. The bud eyes of European grapes in dormancy can tolerate a temperature as low as –15ºC, and freeze injury may occur at –16 to –17ºC.

Grapes show a strong drought tolerance and can be grown in regions where the annual precipitation is 350 - 1,200 mm (Wang 1984). However, too much precipitation may lead to pests and diseases in grapes. Grapes are not particular about soil, and gravelly loam and sandy loam with a loose texture and good ventilation are the most appropriate soils for the growth of grapes. The influencing factors for the growth and quality of grapes were determined, based on the distribution of growing areas of grapes in Beijing, as shown in Table 1. The comprehensive scores based on which five levels of suitability, namely, most suitable, fairly suitable, suitable, unsuitable and most unsuitable were given.

Fig. 9 shows that the major growing areas of grapes are found in the piedmont gentle plain areas and plain areas in the middle and west, as well as plain areas in the east. A small patch of soil in the river basin in Miyun is also most suitable for the growth of grapes. The plain areas in the south are mainly composed of sandy soil and suitable for growing grapes. There are also some suitable growing areas in Yanqing river valley. Extensive mountainous areas in Beijing are not suitable for growing grapes due to low temperature and thin soil layer.

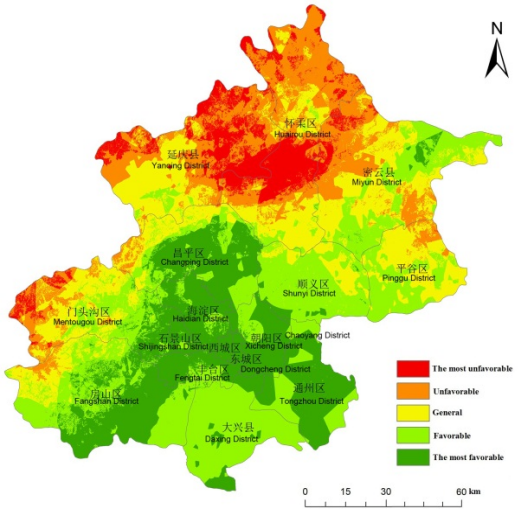


Fig. 9. Distribution of areas suitable for growing sand pear grape trees in Beijing.

Due to urbanization the growing areas of grapes have been decreasing in Beijing in the past 10 years because of a dramatic reduction in the conventional growing areas in Tongzhou and Daxing. In addition, the labor cost remains high, which leads to the high price of grapes and lacks the motivation for the planters. At present, the total growing area of grapes is 2.9 thousand hectares, accounting for 2.1% of the total growing area of fruit trees (Table 2). Beijing has put forward the development strategies for grape wine, with the emphasis placed on chateau wines. The major growing areas of grapes are found in Yanqing, Fangshan, Daxing and Miyun, which account for about 90% of the total growing area of grapes in Beijing. Favorable government policies for promoting the yield and quality of grape wine are important for a healthy development of the grape wine industry. There are four regions with concentrated grape planting in Beijing, namely, the plain area in the east, the cold areas in Yanqing, as well as the growing areas in Fangshan, and the river valley in Miyun. Besides, the piedmont regions of Changping and river valley in Huairou are also most suitable areas for growing grapes, though the growing areas are very limited. They can also be developed as new growing areas for grapes.

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**References**

Cai F, Yu GR, Zhu QL, He HL, Liu XA, Li ZQ and Guo XB 2005. Comparison of precisions between spatial methods of climatic factors, a case study on mean air temperature. Resour Sci. **27**(5): 173-179.

Chen SM and Huang SB 1988 Fruit-tree Meteorology, Beijing: Meteorology Publishing House. pp. 354-392.

Guo ZX, Zhu L, Li XM, Bai QF and He WL 2010a Climate division of Chinese Ripening Pear in Shaanxi based on GIS. Nonwood Forest Research **28**(2): 88-91.

Guo ZX, Li X M, Zhu L, Bai QF and Liang Y 2010b Climate division of Chinese white pear in Shaanxi based on GIS. Journal of Fruit Science **27**(5): 698-702.

Han PP 2010 Study on suitability division of five main economic forest in Shanxi province. Xian, Northwest Agriculture and Forestry University,

Huang SB, Chen ZY, Shen CD, Mcintyreg N and Bridgman HA 2000. A Study on Climatic Subdivisions for the Viticulture in China. Journal of Zhejiang University (Agric. Life Sci.) .**26**(6): 670-674.

Li Q, Wang Y, Lin Y, Li J, Li J, Zhang XY and Li YH 2013. Agricultural Climate Regional Planning of'Red Fuji'Apple in Liaoning Province Based on GIS. Chinese Agricultural Science Bulletin **29**(28): 173-178.

Li Z. 1984 Peach germplasm and breeding in china. Hort. Science 19(3): 348-351.

Li ZL, Luo WH and Pang ZC 1994. Fuzzy cluster analysis on climatic conditions of world's major peach-growing areas and their relations to the ecotypes of peach genetic resources. Chinese Journal of Applied Ecology **5**(3): 245-250.

Luo GG, Wu XY and Leng P 2001. Study on Climatic Zoning for Wine-grape Growing in Huabei Regions. Acta Horticulturae Sinica **28**(6): 487-496.

Tang GA and Yang X 2017. ArcGIS experimental tutorial on spatial analysis of geographic information systems (Second Edition). Beijing: Science Press.

Wang YL 1984. A study of the regionalization of grape production in China. Journal of Fruit Science **1**: 1-7.

Wang YL, Zong XP and Wei WD 1984b. Study on the regionalization of peach growing in china. Fruit Science **2**: 12-24.

Yin MY, Liu XS, Quan WT and Wang Y 2014. Precise Comprehensive Agricultural Climate Regional of 'Fuji' apple in Xianyang Based on GIS. Shaanxi Journal of Agricultural Sciences **60**(9): 46-49.

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