Grape planting situation and regional spatial analysis in Xinjiang, China

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Abstract. With the rapid development of China's grape industry and the improvement of breeding and cultivation management technology, great changes have taken place in Xinjiang grape planting. By the investigation of grape planting distribution in recent ten years in China, using geographic information technology (GIS) to analyze the changes of Xinjiang grape production layout and agglomeration characteristics, summed up the layout and development of Xinjiang grape industry, in order to provide reference for optimizing regional grape variety structure. The results showed that the grape industry in Xinjiang has entered a high-quality development stage, grape planting in the spatial distribution showed an expansion trend, the degree of concentration and imbalance was slightly reduced, the regional layout and variety structure were optimized to some extent, but the grape industry in Xinjiang was still in a high degree of centralized distribution

1. Introduction
Grape production is an important part of China's fruit industry and occupies an important position in the world fruit market [1-3]. Through nearly ten years of development, China's table grape cultivation area and yield ranked first in the world in 2014 [4]. In 2017, the grape cultivation area reached 706600 hm², and the yield reached 1.3083 million tons [5]. With the continuous increase of grape cultivation area and yield, grape industry has become a vital pillar to promote regional economic development and rural revitalization, playing an important role in China’s agricultural economy [6-9].

Xinjiang Uygur Autonomous Region, as the traditional representative of arid and semi-arid grape production areas in Northwest China [10], has rich light and heat resources and diverse geographical environment, which provides unique growth conditions for grape growth, making it the dominant production area of table and dried grapes in China, and has long occupied the primary position of grape production in China, which has played an important role in local rural economic development and farmers' continuous income increase [11-15]. In recent years, with the rapid development of China's
grape industry and the continuous improvement of planting level, grape planting has developed from traditional superior production areas to all provinces and regions in China, especially the planting area of southern regions has increased rapidly [16-18]. Therefore, fully understanding the spatial distribution and development trend of grape production in Xinjiang is of great practical significance for regional advantages and production resource allocation [19-21].

Previous researchers have done lots of researches on grape distribution division and change rules in China, but most of them focused on wine grape distribution or climate division [22-27]. There are few studies on table grape, dried grape and wine grape’s covering areas, especially in Xinjiang grape production areas.

Therefore, by investigating the grape planting distribution and industrial development trend in both Xinjiang and the whole China in recent ten years [28-32], using GIS to analyze the changes and agglomeration characteristics of grape production layout, sum up the distribution and development rules of grape industry in Xinjiang, and draw the layout map of grape industry in Xinjiang, aiming to provide reference for optimizing the regional distribution of grape varieties in Xinjiang and providing scientific basis for promoting the high quality development of grape industry in Xinjiang.

2. Materials and methods

2.1. Overview of the study area
Xinjiang Uygur Autonomous Region is located in 73°40′~96°18′ E, 34°25′~48°10′ N, the northwest border of China, with a total area of 166.49×10⁴ km². It is the provincial administrative region with the largest area and the most neighboring countries in China. It has jurisdiction over 24 districts including 4 prefecture level cities, 5 autonomous prefectures, 5 regions and 10 counties directly under the central government. Xinjiang is located in the hinterland of Eurasian continent and belongs to the typical temperate continental arid climate. The annual sunshine hours are 2500~3500h, the frost free period is 150~240d, the average annual precipitation is about 150 mm, and the average annual evaporation is more than 1000 mm. The Tianshan Mountains divide Xinjiang into two parts: the northern Xinjiang and southern Xinjiang. The annual average temperature, sunshine hours and other heat conditions in southern Xinjiang are better than those in Northern Xinjiang, while water resources conditions such as annual precipitation and river run off in Northern Xinjiang are better than those in southern Xinjiang [31, 33].

2.2. Data sorting and collection
The 1:10,00000 vector data in national basic geographic information system is used for Chinese map and Xinjiang map, including the boundary data of administrative divisions of provinces, cities and counties [34]. Climate division data and 1km digital elevation model (DEM) are from the Resource and Environment Science and Data Center [35]. The data of grape cultivation area and yield are respectively from China Statistical Yearbook (2008-2018) [30], Xinjiang Statistical Yearbook (2008-2018) [28], Xinjiang production and Construction Corps Statistical Yearbook (2008-2018) [29], National Bureau of statistics [30], Xinjiang Uygur Autonomous Region Statistics Bureau [31], Xinjiang production and Construction Corps Statistics Bureau [32] and other official network statistical data, of which Guangdong, Hainan, Taiwan, Hong Kong and Macao provinces (special administrative regions) have no data or statistics, thus data of grape cultivation area and yield in these provinces or special administrative regions are calculated as zero.

2.3. Data processing and analysis
The data of grape cultivation area and yield in Xinjiang in this study refers to the sum data of Xinjiang Uygur Autonomous Region and Xinjiang Production and Construction Corps. In this study, the data of Xinjiang Production and Construction Corps are divided into the cities (counties) where the divisions of Xinjiang Production and Construction Corps are located. Microsoft Excel 2007 and ArcGis 10.5 version were used to make the trend map, distribution map and region division map of grape cultivation, and the
regional Gini coefficient ($C_k$) was used to express the imbalance of geographical distribution [21], and the formula was as follows:

$$C_k = \frac{2}{n} \sum_{i=1}^{n} i \times X_i - \frac{n+1}{n}, X_i = \frac{Y_i}{\sum_{i=1}^{n} Y_i}, (X_1 < X_2 < ... < X_n)$$

In the formula: $X_i$ means the proportion of grape yield of each prefecture (city) in the total grape yield of Xinjiang, which arranged in low to high, $Y_i$ is the grape yield of each prefecture or city, and $n$ is the number of prefectures (cities).

3. Results and analysis

3.1. Development of grape production in China

2007-2017 was the stable development period of China's grape industry, the planting area increased from 427300 hm$^2$ in 2007 to 706600 hm$^2$ in 2017, area in 2017 was 1.65 times of area in 2007; the yield increased from 6.7089 million tons in 2007 to 13.0829 million tons in 2017, yield in 2017 was 1.95 times of yield in 2007. From 2007 to 2017, China's grape cultivation area has increased 65.36%, with an average annual growth rate of 5.24% (Fig. 1). Among which, the growth rate was the fastest in 2012, reaching 11.35%. There were two consecutive years of negative growth from 2016 to 2017, with the growth rates of -1.35% and -0.03%, respectively. From 2007 to 2017, China's grape yield increased 95.01%, with an average annual growth rate of 7.04%. Among which, the fastest growth rate was in 2012, reaching 16.66%. In 2016, there was a negative growth rate of -4.06%, but it recovered to 3.59% in 2017.

![Figure 1. The grape area and yield in China in 2007-2017](image)

3.2. Changes of grape yield and distribution in China

According to Fig. 2, it can be seen that in 2007, there were 12 provinces and regions with grape planting area of more than 10000 hm$^2$, including Xinjiang, Hebei, Shandong, Liaoning, Henan, Hunan, Sichuan, Shaanxi, Jiangsu, Zhejiang, Guangxi and Jilin, of which Xinjiang, Hebei and Shandong ranked the top three in China, accounting for 64%, 12.62% and 9.45% of the grape planting area in China, which accounting for 47.71% of the total grape area in China. Xinjiang was the only region with a yield of 1.6546 million tons, ranking the first in China, while Hebei and Yunnan were the second and third regions with the yield of 0.9058 million tons and 0.9001 million tons respectively. The yields of these three provinces and regions (Xinjiang, Hebei and Yunnan) accounted for 24.66%, 13.50% and 13.42% of the total grape yield in China, accounting for 51.58% of the total yield in China.
Figure 2. The distribution of grape cultivation in China in 2007 (A) and 2017 (B).
By 2017, there were 18 provinces and regions had more than 10000 hm$^2$ of grape planting area in China, namely Xinjiang, Yunnan, Shaanxi, Hebei, Shandong, Henan, Jiangsu, Guangxi, Zhejiang, Sichuan, Liaoning, Hunan, Guizhou, Ningxia, Anhui, Gansu, Hubei and Shanxi. Among them, Xinjiang, Yunnan, Shaanxi, Hebei and Shandong ranked the top five in China, accounting for 18.92%, 7.86%, 6.33%, 6.05% and 5.35% of China's grape planting area, respectively, which accounting for 50% of the total grape area in China. There were four provinces and autonomous regions with the yield of more than 1 million tons, which were Xinjiang, Yunnan, Hebei and Shandong, accounting for 19.05%, 9.67%, 8.53% and 8.40% of China's total grape yield, respectively, which accounting for 45.65% of the total yield of China.

Xinjiang, Hebei and Shandong have been the major grape planting provinces in China in recent ten years, especially Xinjiang, which has always ranked the first in the area and yield of grape planting in China. Yunnan, Shaanxi and Guangxi provinces have developed rapidly as the grape cultivation area in Yunnan has increased from 7240 hm$^2$ to 55520 hm$^2$, the area rank has risen from the 15th to the second in China. The grape cultivation area in Shaanxi has increased from 14800 hm$^2$ to 44740 hm$^2$, the area rank has risen from the 8th to the third. The grape cultivation area in Guangxi has increased from 11090 hm$^2$ to 33880 hm$^2$, the area rank has risen from 11th to 8th. While the grape cultivation area in Jilin Province decreased from 10150 hm$^2$ to 4930 hm$^2$, the area rank has decreased from the 12th to the 23rd. The six provinces of the new grape cultivation area were Guizhou, Ningxia, Anhui, Gansu, Hubei, Shanxi with the area more than 10000 hm$^2$, and the total cultivation area was 110440 hm$^2$, accounting for 15.63% of the whole China, showing a strong development trend.

3.3. Overview of grape production in Xinjiang

From 2007 to 2017, the grape cultivation area in Xinjiang was in a slow growth period, the planting area increased from 109900 hm$^2$ in 2007 to 143900 hm$^2$ in 2017; however, the yield has increased from 165.4600 million tons in 2007 to 270.5700 million tons in 2017, which was 1.64 times of that in 2007 (Fig. 3). From 2007 to 2017, the grape cultivation area in Xinjiang increased by 31.02%, with an average annual growth rate of 2.82%, which was lower than the national average level. The fastest growth rate was 9.24% in 2010, while there was a negative growth occurred in 2008, 2016 and 2017, with growth rates of -1.00%, -0.84% and -3.39%, respectively. From 2007 to 2017, Xinjiang's grape yield increased by 65.53%, with an average annual growth rate of 5.47%, which was lower than the national average level, and the yield fluctuated a lot. Among which, the fastest growth rate was 19.14% in 2012, while the negative growth occurred in 2008, 2011 and 2016, with the growth rates of -0.35%, -10.73% and -2.91%, respectively. The yield decline had a relationship with the decreasing grape planting area in 2008 and 2016. However, when the cultivation area of grape increased in 2011, the yield of grape had the maximum decline. The study showed that it had a great relationship with the disastrous climate such as strong wind and late spring cold in Xinjiang.

![Figure 3. The grape area and yield in Xinjiang (2007-2017).](image-url)
3.4. Changes of grape yield and distribution in Xinjiang

According to Fig. 4, in 2007, there were two places with grape planting area of more than 10000 hm$^2$, namely Turpan and Hotan, with 30144 hm$^2$ and 10375 hm$^2$ respectively. Shihezi ranked the third in Xinjiang, with planting area of 9145 hm$^2$, accounting for 27.44%, 9.44% and 8.32% of the total grape planting area in Xinjiang, which accounting for 45.21 % of the total grape area in Xinjiang. There are four prefectures (cities) with a yield of more than 0.1 million tons, namely Turpan, Urumqi, Hotan and Changji, the yields were 0.7687 million tons, 0.1484 million tons, 0.1373 million tons and 0.1157 million tons, respectively, accounting for 46.46%, 8.97%, 8.30% and 6.99% of the total grape yield, which accounting for 70.72% of the total yield in Xinjiang.

By 2017, there were five prefectures (cities) ranking among the top five with grape planting area of more than 10000 hm$^2$ in Xinjiang, which were successively followed by Turpan, Ili, Bayingolin, Shihezi and Hotan, accounting for 25.57%, 11.96%, 11.36%, 8.25% and 7.71% of Xinjiang's grape planting area respectively, which accounting for 64.86% of the total grape yield in Xinjiang. There were 9 prefectures (cities) with a yield of more than 0.1000 million tons, including Turpan, Ili, Hotan, Shihezi, Hami, Aksu, Kokdala, Kashi (kaxgar) and Shuanghe, accounting for 36.80%, 9.58%, 8.19%, 7.49%, 6.99%, 5.53%, 4.41%, 3.93% and 3.73% of Xinjiang's total grape yield, which accounting for 86.66% of the total yield of Xinjiang.
Figure 4. The distribution of grape cultivation in Xinjiang in 2007 (A) and 2017 (B)

Turpan and Hotan have been the largest grape planting areas in Xinjiang in recent ten years, especially the grape planting area and yield in Turpan always ranked first in Xinjiang, with Ili, Bayingolin, Hami and other prefectures (cities) have developed rapidly. The grape cultivation area in Ili has increased from 5242 hm$^2$ to 17221 hm$^2$, ranked from the 15th place in Xinjiang to the second place. The grape cultivation area in Bayingolin has increased from 7273 hm$^2$ to 16351 hm$^2$, ranked from the sixth to the third place in Xinjiang. The grape cultivation area in Hami has increased from 4047 hm$^2$ to 9095 hm$^2$, ranked from 11th to the 6th. While the grape cultivation area in Urumqi decreased from 8984 hm$^2$ to 3680 hm$^2$, ranked from the fourth to the 15th. Three prefectures (cities) which were Ili, Bayingolin, Shihezi had more than 10000 hm$^2$ of grape cultivation area, with a total cultivation area of 45441 hm$^2$, which accounting for 31.57% of the whole area in Xinjiang, showing a strong development trend.

3.5. Location Gini coefficient of grape industry in Xinjiang

Location Gini coefficient is a commonly used index to measure the industrial concentration. It is often used to measure the agglomeration degree of production scale distribution in the region, and can also be used to describe the imbalance of industrial geographical distribution. Generally speaking, the larger the value of $C_k \in [0, 1]$ is, the more uneven the distribution is. It is generally believed that a value of $C_k < 0.20$ indicates a high degree of dispersion, while a value of $C_k > 0.50$ indicates a high degree of concentration. In 2007 and 2017, the $C_k$ values were 0.7565 and 0.7161, respectively, indicating that the regional distribution of grape planting in Xinjiang was still highly concentrated. Although the $C_k$ value decreased by 5.33%, the scale distribution still showed an obvious imbalance.
3.6. Development planning and objectives of Xinjiang grape industry

3.6.1. Climate division of Xinjiang. The grape cultivation is an agricultural system that is extremely sensitive to climate. According to the climate division of China [35], Xinjiang is mainly divided into zones, namely middle temperate zone, southern temperate zone and plateau climate zone (Fig.5 A). For the most parts of Xinjiang belong to middle temperate zone and southern temperate zone, with the effective accumulated temperature (AAT) is 1600~3400 °C, and the altitude is 1000~2000m. A small part of the region belongs to plateau climate zone, with AAT < 2000 °C and altitude > 2000m, the average annual temperature is less than 0 °C (Fig.5 B and C). The AAT required by different grape varieties from germination to full ripening of fruit is different, and 2100°C is the minimum requirement for grape growth season [23]. It can be concluded that most areas of northern Xinjiang, Yining, Menggan and southern Xinjiang area suitable for grape planting with average AAT>3500 °C and average annual temperature > 7.2 °C. However, grape planting is not suitable in northern Tibet, Qingnan and Qaidam regions.

According to the climate conditions, the average annual precipitation of Turpan and the west of Hami is less than 50 mm (Fig. 5 D), and the average annual temperature is more than 10°C, these two regions are suitable for the development of table grape and dried grapes, such as ‘Thompson seedless’, ‘Centennial seedless’, ‘Perlette’, early and other middle maturing varieties; Hotan is more suitable for the development of table grapes, such as ‘Hetianhong’, ‘Hetianhuang’, ‘Hetianlv’ and other middle and late maturing varieties; Kizilsu Kirghiz and Kashi (kaxgar) are suitable for the development of late maturing varieties such as ‘Hashihaer’, ‘Hongmuncage’ and ‘Lumunage’; the average annual temperature of Ili, Changji and Shihezi is 0~7.2°C, and the precipitation is about 200 mm, which is conducive to the accumulation of terpenes, pyrazines, esters and other substances. These regions are suitable for the mixed development of some table grapes and wine making varieties that are resistant to storage and transportation, such as ‘Red Globe’, ‘Kyoho’, ‘Cabernet Sauvignon’, ‘Merlot’, ‘Marselan’ and other varieties.

![The Temperature Zone of Xinjiang](image)
The Altitude of Xinjiang

The Annual Temperature of Xinjiang
Figure 5. The Climate and altitude of Xinjiang

3.6.2. *Table and dried grapes*. According to statistics, by 2019, the planting area of table and dried grapes in Xinjiang has reached 84300 hm², and the yield was 2.2617 million tons, ranking the first place in China, which is the main production area of raisins in China. According to the regional layout planning of advantageous and characteristic agricultural products in Xinjiang Uygur Autonomous Region (2020-2025) (excluding Xinjiang Production and Construction Corps), the planting area of table and dried grapes in Xinjiang will be stable at about 100000 hm² by 2025, and the yield will reach more than 2.500 million tons. It is mainly distributed in Turpan & Hami basin, northern slope of Tianshan Mountain, Ili River Valley, Yanqi Basin and surrounding Tarim Basin, including on 11 counties and cities (Fig. 6 A), including Gaochang district and Shanshan County of Turpan City, Yutian County, Moyu County and Hetian County of Hotan region, and Atux City of Kizilsu Kirghiz prefecture, Huocheng County, Yining County of Ili prefecture, Yizhou District of Hami City, Kaxgar City, Shule County of Kashi (kaxgar) region, which are mainly focused on the development of table and dried grape varieties (Fig. 6 B).
Figure 6. The distribution of grape (A, B) and vinifera (C, D) in Xinjiang in 2025.
3.6.3. Wine grape. By 2019, the planting area of wine grape in Xinjiang was 19700 hm$^2$ and the yield was 89200 t. At present, four major production areas and a relatively complete industrial system have been formed in the northern slope of Tianshan Mountain, Ili River Valley, Yanqi Basin and Turpan & Hami basin. According to the development plan of the autonomous region, by 2025, the planting area of wine grape in the region will reach about 26700 hm$^2$, and the yield will reach more than 180000 tons. It is mainly distributed in the northern foot of Tianshan Mountain, Ili River Valley, Turpan & Hami basin and Yanqi basin, involving Changji prefecture, Ili prefecture, Turpan city and Bayingolin prefecture (Fig.6 C). Among them, the northern slope of Tianshan Mountain is mainly distributed in Manas county and Changji city of Changji prefecture; Ili River Valley is mainly distributed in Yining city and Yining county directly under Ili prefecture; Turpan & Hami basin is mainly distributed in Gaochang district and Shanshan County of Turpan city; Yanqi basin is mainly distributed in Yanqicounty and Heshuo county in Bayingolin prefecture (Fig. 6 D).

4. Discussion
China's grape industry has achieved remarkable progresses through the steady development in the past decade. Not only has the planting area and yield achieved steady growth, but also the structure and quality of grape products have made a qualitative leap [6-8]. As of 2017, China's grape planting area was 427300 hm$^2$, and the yield was 13.0829 million tons [30], an increase of 65.36% and 95.01% respectively compared with the year of 2007. With the continuous improvement of grape breeding and cultivation technology in China, the grape planting area has also expanded, which has changed the temporal and spatial pattern of grape production in China, and improved the grape cultivation technology system in different ecological regions. Grape production has now spread over 28 provinces (autonomous regions) and cities in China [8, 19]. Eight grape production regions have been formed, including northwest China, Loess plateau, Yellow River old channel, Yanhuai River valley, Bohai bay, Central and East China, Southwest China and Northeast China [10].

Northwest China, led by Xinjiang, is the largest grape production region in China [10, 30]. In 2017, Xinjiang's grape cultivation area and yield reached 20.37% and 20.68% of China, respectively [28, 30]. Under the background of the rapid development of grape industry in China, the grape industry in Xinjiang has been in a stable development stage in recent ten years. Compared with 2007, the planting area increased by 34073 hm$^2$, the yield increased by 1.0511 million tons, and the growth rates were 31.02% and 65.53%, respectively. Xinjiang has achieved the overall stable area and improved yield in grape production. With the scientific layout and coordinated development of forestry and fruit industry in Xinjiang, grape planting areas have also developed from centralized to decentralized. The number of regions with an area of more than 10000 hm$^2$ have developed from 2 to 5, and the number of regions (cities) with a yield of more than 0.10 million tons have developed from 4 to 9, which have indicated that the regional layout of grape has gradually become expand and reasonable. The proportion of grape in fruit area and yield also decreased from 17.99% and 40.16% to 15.08% and 26.01%, respectively, which initially realized the optimization and adjustment of fruit and forestry structure.

5. Conclusion
In recent ten years, although Xinjiang has made some development and progress in grape industry, the spatial distribution of grape planting has shown an expansion trend, and the overall concentration and imbalance degree have been declined, there is still a big gap compared with the developed regions at home and abroad, such as high concentration of production area distribution, insufficient regional layout, uneven cultivation techniques, etc. Therefore, it is still necessary to make full use of the geographical environment and climate resources in Xinjiang, and make more precise and detailed layout and planning for different regions, especially for the non-traditional grape planting areas and the undeveloped grape growing areas in southern Xinjiang, thus the future planning should be as detailed as possible to each county or even township, and pay attention to the regionalization of different varieties in the same area. At the same time, it is also very important to strengthen the grape breeding, cultivation management, storage and processing technology research and promotion, in order to better promote the high-quality
and coordinated development of Xinjiang grape industry, and play a greater role in Xinjiang regional economic development.

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