Article

The Spatial Pattern of Ski Areas and Its Driving Factors in China: A Strategy for Healthy Development of the Ski Industry

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Abstract: The development of ski areas would bring socio-economic benefits to mountain regions. At present, the ski industry in China is developing rapidly, and the number of ski areas is increasing dramatically. However, the understanding of the spatial pattern and driving factors for these ski areas is limited. This study collected detailed data about ski areas and their surrounding natural and economic factors in China. Criteria for classification of ski areas were proposed, and a total of 589 alpine ski areas in China were classified into three types: ski resorts for vacationing (va-ski resorts), ski areas for learning (le-ski areas) and ski parks to experience skiing (ex-ski parks), with proportions of 2.1%, 15.4% and 82.5%, respectively, which indicated that the Chinese ski industry was still dominated by small-sized ski areas. The overall spatial patterns of ski areas were clustered with a nearest neighbor indicator (NNI) of 0.424, in which ex-ski parks and le-ski areas exhibited clustered distributions with NNIs of 0.44 and 0.51, respectively, and va-ski resorts were randomly distributed with an NNI of 1.04. The theory and method of spatial autocorrelation were first used to analyze the spatial pattern and driving factors of ski areas. The results showed that ski areas in cities had a positive spatial autocorrelation with a Moran's index value of 0.25. The results of Local Indications of Spatial Association (LISA) showed that ski areas were mainly concentrated in 3 regions: the Beijing-centered Yanshan-Taihang Mountains and Shandong Hill areas, the Harbin-centered Changbai Mountain areas and the Urumqi-centered Tianshan-Altay Mountain areas. The first location was mainly driven by socio-economic factors, and the latter two locations were mainly driven by natural factors. Ski tourism in China still faces many challenges. The government sector should strengthen supervision, develop a ski industry alliance, and promote the healthy and sustainable development of the ski industry in the future.

Keywords: ski areas; spatial pattern; driving factors; spatial autocorrelation; development strategy

1. Introduction

Today, skiing is a competitive winter sport or a recreational activity, and resorts mainly rely on snow and climate resources. However, skiing first appeared north of the Arctic Circle and in the Altay Mountains of China, mainly for transport, hunting and war effort [1,2]. After the Second World War, the global economy developed rapidly, and Europe and the United States led the skiing boom globally, which resulted in the development of ski tourism and resulted in skiing becoming a popular winter sport [3,4]. Abundant snow resources and favorable topographic conditions in mountainous areas are the foundation of alpine skiing. The ski industry, as a component of the tourism sector, has not only

injected renewed economic vitality into alpine hamlets to avoid population loss but also promoted the economic growth of mountain areas [5–8]. With the flourishing development of the ski industry, a great quantity of research has been carried out, mainly focusing on the operation management and service quality of ski resorts [9–13], skiing equipment improvement and injury prevention [14–20] and avalanche risk prediction in skiing [21–23]. These studies not only provide a theoretical basis for the long-term and stable development of the ski industry but also provide technical support and security guarantees for skiers.

At present, ski tourism, as a typical snow-dependent industry, is threatened by global climate change. The decrease in the extent and duration of snow caused by high temperature and changed precipitation will be an immense challenge for the alpine ski industry globally [24–26]. The developed areas, such as Alpine countries, North America, Japan and South Korea, have substantial research on the reliability and sustainability of ski resorts and ski conditions, particularly in the context of global warming [6,27–33]. The results showed that the shortened ski season length, the decreased snow abundance and snowpack duration with skiability, the reduced snow quality and the increased water usage for snow-making have been the top challenges for the ski industry, particularly in low latitude, low altitude and small-sized resorts.

As a country rich in mountains, China has great potential for developing ski tourism. However, due to historical reasons, modern skiing in China started as late as the 1980s, with fewer ski areas and inadequate infrastructure. In 1996, the Asian Winter Games were held in Harbin, Heilongjiang Province, which introduced skiing in China onto the international sports arena. Since then, China has begun to build market-oriented ski resorts, and the ski industry has entered a period of rapid development and construction but is still dominated by small- to intermediate-sized fields [34,35]. With the successful bid of Beijing-Zhangjiakou for the 2022 Winter Olympic Games, the ski industry in China is developing very rapidly and is entering its golden period. The goal of having 300 million Chinese participants in winter sports, which was proposed by Chinese President Xi Jinping, has greatly promoted the enthusiasm of the public. According to statistics of annual report on development of ski industry in China [36], the number of ski resorts / areas has increased from 270 in 2010 to 703 in 2017, and ski tourists have increased nearly 2 times. The proposed goal by Chinese President Xi has effectively promoted the popularity of skiing and has produced positive social and economic benefits.

However, the development of China's ski industry, compared with that of developed countries, is still in the primary stage and faces certain challenges, including (1) unreasonable site selection and the lack of unified standards for the construction of ski areas [35,37,38]; (2) a large proportion of small- and medium-sized ski areas, imperfect supporting facilities and relatively out of date piste conditions (small vertical drops, gentle slopes and inadequate natural snow resources, etc.) [39,40]; and (3) low probability that tourists will visit again [36]. The related theoretical research is also insufficient. Most of the existing studies adopt qualitative methods to analyze the development statuses, problems and challenges of China's ski industry [41–45]. There are also some studies focusing on the distribution of ice and snow resources and ecological suitability in the Zhangjiakou-Beijing region against the backdrop of the Winter Olympic Games [46–49]. Moreover, quantitative and intuitive analysis methods such as the comprehensive index system, model evaluation and spatial analysis in recent research have been applied to reveal the suitability of winter tourism destinations in China, which indicate the transition from qualitative to quantitative in theoretical research of Chinese ski tourism [40,50–52]. However, the suitability analysis is mostly based on climate and resource distribution, and the related studies on the spatial pattern and driving factors of different type ski areas are still insufficient.

As one of the rapidly developing areas of future ski tourism, it is one of the most important challenges in China and even internationally whether the spatial pattern of ski resorts is reasonable and how to adapt to global climate change in the future. This study aims to reveal the spatial pattern of China's ski areas and to explore its driving factors based on GIS spatial analysis theory to provide a theoretical basis for the sustainable development of the ski industry in China.

2. Data and Methods

2.1. Data Sources

To directly analyze the spatial distribution of winter recreation locations and their potential impact factors, a series of natural and social factors was analyzed in this work. The natural factors included topographic features (elevation, terrain slope and geomorphology), snow conditions (maximum and mean snow depth and duration of snow cover) and climate conditions (mean air temperature and precipitation). The social factors comprised economic conditions (the gross domestic product (GDP) per capita), population conditions (the population density) and traffic conditions (the cost distance to provincial, capital and cities). All data were collected and prepared at a national scale. The snow season was regarded as lasting from November to March of each year; thus, average values of climate and snow in the winter were used to characterize the corresponding spatial distribution. The study period was from 1986 to 2015.

The obtained data used in this work contained numerous aspects. The locations of ski areas were obtained through the Baidu map application program interface (API) and corrected by Google Earth. Finally, we obtained 620 ski areas, including 589 alpine ski areas, 29 indoor snow centers and 2 non-operational snow fields for backcountry skiing. The digital elevation (DEM) and slope with a resolution of 30 m were originally from ASTER GDEM V2; a classified geomorphologic map of China at a scale of 1:1000,000, and grid datasets of the GDP and population density with a resolution of 1 km were obtained from Resources and Environmental Scientific Data Center (RESDC), Chinese Academy of Sciences (CAS); the monthly datasets of the grid-based surface air temperature with a spatial resolution of 0.5×0.5 degrees, and precipitation were obtained from National Meteorological Information Center of China; the daily dataset of the snow depth was retrieved by the revised Chang algorithm [53] with passive microwave brightness temperatures of the SMMR (1979–1987), SSM/I (1987–2007) and SSMI/S (2008–2016), and was obtained from Environmental and Ecological Science Data Center for West China; and the average snow cover duration data during 2000–2016 were from multi-source remote sensing data by Y. Wang et al. [54]. Traffic data including highway and railway were obtained from the national fundamental geographic information dataset at a 1:1000,000 scale from National Catalogue Service For Geographic Information. Traffic accessibility was calculated based on the gravity model [55].

2.2. Methods

2.2.1. Classification Criteria for Ski Areas in China

With the rapid increase in ski areas in China, government departments and related enterprises have formulated a series of regulations to strengthen the guidance and supervision of the development and management of ski resorts while promoting the interests of ski sportsmen and other skiers. The regulations for the management of China's ski areas were published and issued in 2005 by the Winter Sports Management Center of General Administration of Sport of China and the Chinese Ski Association. The first and second revisions of the regulations were made in 2013 and 2017, respectively. A series of requirements, such as the total area of ski runs, snow thickness after compaction, and average and maximum slope of pistes, were included [56].

In 2014, the China Tourism Bureau issued a quality grade division of tourist ski areas, which comprehensively assessed the level of ski areas according to their equipment and facilities, climate and environment, tourist traffic, safety and insurance, health, communication network, shopping, comprehensive management and service. There were five quality levels that ranged from the highest (5S) to the lowest (S). The requirements of total length, slope and snow thickness of pistes in different level ski areas were introduced as standards [57].

In 2017, an annual report of the ski industry in China by Sun et al. [36] and 2017 China Ski Industry White Book by Wu and Wei [36,58], divided Chinese ski areas from several perspectives: the target

visitors attracted by ski areas (enthusiasts, local inhabitants or sightseers), vertical drop of ski areas (>300 m, between approximately 100 and 300 m, or <100 m), total area of ski runs (>100 ha, between approximately 50 and 100 ha, or <50 ha) and total number of ski tourists (>150 thousand, between approximately 50 and 150 thousand, or <50 thousand).

However, due to the limited data available for ski areas, many indicators in the above classification criteria cannot be obtained. Therefore, we selected specific indexes including the length and total number of pistes, the area of snow-making, the number of advanced pistes and lifts, and the availability of accommodation facilities, as the new classification criteria. These indexes can better reflect scale of ski areas and the threshold is determined by combining the existing classification standards and adjusted based on actual situation of ski areas. More details are listed in Table 1. According to the definition of Vanat that a ski area is an organized and operated place for skiing with fewer trails and usually less than or equal to four lifts, while a ski resort is considered a large ski destination with more than four lifts [59], we reclassified the ski areas into three types: ski resorts for vacationing (va-ski resorts), ski areas for learning (le-ski areas) and ski parks to experience skiing (ex-ski parks). The ski resorts for vacationing (va-ski resorts) refer to a large holiday destination with more than 4 ski lifts located in mountain areas with steep landforms and having various types of ski trails, which is consistent with international standards and provides advanced accommodation facilities. Va-ski resorts usually involve a large amount of overnight consumption, and the average stay time of guests is longer than 1 day. The ski areas for learning (le-ski areas), intermediate size resorts, are located in low-relief mountains and hills surrounding the outskirts of cities and usually include rest areas but no hotels. This type of ski area is dominated by primary and intermediate pistes, with less advanced runs. Local inhabitants may account for a large proportion of the visitors, with an average staying time of approximately 3–4 h. Ski parks to experience skiing (ex-ski parks) are small size ski areas with less than 1 lift, and are usually located in scenic spots or suburbs, where the mountain terrain is gentle, the facilities are generally simple, e.g., only simple ski runs, more than 90% of the visitors are inexperienced one-time skiers, and the average staying time is 2 h.

Table 1. Classification criteria of ski areas.

Type	Length of Piste (km)	Area of Snow-Making (ha)	Total Pistes	Advanced Pistes	Total Lifts	Presence of Resort Hotels
Va-Ski Resorts	>10	>75	≥15	≥5	>4	Yes
Le-Ski Areas	2~10	10~75	5~15	1~5	1~4	No
Ex-Ski Parks	<2	<10	<5	0	<1	No

2.2.2. Nearest Neighbor Indicator

We used the nearest neighbor indicator (NNI) to identify the overall spatial pattern of ski areas. This index compares the distribution of objects with a random distribution to whether they are random, clustered or dispersed. A ratio of the average distance of the nearest neighboring points to the average distance of the random distribution model is calculated [60], and the formula is as follows:

$$NNI = \frac{\sum_{i=1}^n \frac{\min(d_{ij})}{n}}{0.5 \sqrt{(A/n)}} \quad (1)$$

where NNI is the index of the distance ratio; $\min(d_{ij})$ is the distance between ski area i and its nearest neighbor j ; n is the total number of ski areas; and A is the total area of the study zone.

When $NNI = 1$, the spatial pattern of the samples is a random distribution, $NNI < 1$ indicates a clustered pattern and $NNI > 1$ means more a more dispersed rather than random pattern.

To test the significance of the results, a Z-score is calculated, and the corresponding P-value can be provided. The Z-score is calculated as follows:

$$Z = \frac{\sum_{i=1}^n \frac{\min(d_{ij})}{n} - 0.5 \sqrt{A/n}}{\sqrt{[(4 - \pi)A] / (4\pi n^2)}} \quad (2)$$

2.2.3. Spatial Autocorrelation, Cluster and Outlier Analysis

Spatial autocorrelation is a widely used concept and method in geographical analysis; it refers to the statistical correlation based on the attribute values of different geographic elements and their distances [61,62]. Generally, the smaller the distance, the greater the correlation between two attribute values. To examine whether the spatial samples are autocorrelated in the study area, Moran's index is the most commonly used index [63–65]. We used Moran's index to analyze the spatial autocorrelation of the ski areas and their influencing factors on the municipal city scale. The index is calculated as follows:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n \omega_{ij} (y_i - \bar{y})(y_j - \bar{y})}{(\sum_{i=1}^n \sum_{j=1}^n \omega_{ij}) \sum_{i=1}^n (y_i - \bar{y})^2} \quad (3)$$

where I represents Moran's index, which varies between -1 and 1 ; n is the number of cities; y_i and y_j represent the attribute values of the variable y at location i and j , respectively; $\bar{y}$ is the average value of y from n samples; and ω_{ij} is the spatial weight matrix, which represents the connection between i and j and can be defined as a function of the inverse of distance d_{ij} .

The hypothesis of Moran's index is that there is no spatial correlation between the subjects. The Z-score is usually used to test the hypothesis, which is determined by the value, expectation and variance of index I ; when the absolute value of Z is greater than 1.96 , it generally means that there is 95% probability of spatial autocorrelation. The formula is:

$$Z = \frac{I - E(I)}{\sqrt{\text{var}(I)}} \quad (4)$$

where $E(I)$ is the expectation of I ; and $\text{var}(I)$ is the variance of I and depends on the distribution characteristic of the attribute values of the objects.

When $0 < I \leq 1$, the attribute value of the spatial objects is positively correlated, while $-1 \leq I < 0$ indicates a negative correlation, and $I = 0$ indicates that there is no spatial correlation, that is, a random distribution.

However, the global spatial autocorrelation index can only provide one overall description of the distribution of spatial objects in the study area. To further investigate the spatial heterogeneity in the objects, local indicators of spatial association (LISA) are developed to measure the local correlation of each spatial object attribute, which can also recognize spatial clusters or spatial outliers [66,67]. The local Moran's index is calculated as follows:

$$I_i = \frac{y_i - \bar{y}}{s^2} \sum_{j=1, j \neq i}^n [\omega_{ij} (y_j - \bar{y})] \quad (5)$$

where y_i is the value of y at location i ; y_j is the value of y at location j (where $j \neq i$); s^2 is the variance of variable y ; and ω_{ij} is the weight of location j on i .

Certain objects will be correspondingly considered spatial clusters or spatial outliers when the local Moran's index values are highly positive or negative. The former implies that the location has similar high or low values to its neighbors, which includes high-high clusters and low-low clusters, while the latter includes high-low or low-high outliers, whose attribute values are notably different from the surrounding locations.

3. Results

3.1. Classification and Spatial Distribution of Ski Areas

In this study, a total of 620 ski areas were obtained, and their locations are shown in Figure 1a. Of these, 589 alpine ski areas were reclassified according to the classification criteria in Table 1. Finally, there were 486 ex-ski parks, 91 le-ski areas, and only 12 va-ski resorts by the end of 2017 in China. Although the number of ski areas has been increasing rapidly in recent years, the Chinese ski industry is still dominated by intermediate- and small-scale ski areas. Ex-ski parks account for 82.5%, with le-ski areas accounting for 15.4% and va-ski resorts accounting for only 2.1%.

Figure 1. Cont.

Figure 1. (a). Spatial pattern of the different types of ski areas; (b). the kernel density of alpine ski areas; (c). the Anselin local Moran's index of the ski areas of cities in China.

The NNI index and kernel density estimation of alpine ski areas were conducted based on ArcGIS software. The results showed that the spatial pattern of ski areas in China were clustered with an NNI of 0.424 and z-score of -26.78 ($p < 0.01$), which means that this clustered pattern had a likelihood of less than 1% of being a random distribution. Le-ski areas and ex-ski parks were also clustered distributions with NNI values of 0.51 and 0.44 and z-scores of -8.95 and -23.57 , respectively. The pattern of va-ski resorts was close to random (NNI = 1.04, z-score = 0.26). The kernel density analysis results (Figure 1b) indicated that the most densely distributed regions were mainly located in the Beijing-centered Beijing-Tianjin-Hebei areas, and its surrounding Taihang Mountain and Shandong Hill areas. The sub-dense areas were located in the Harbin-centered Changbai Mountain areas and Urumqi-centered Tianshan-Altay Mountain areas. They constituted the major areas of the ski industry in China. In recent years, indoor snow centers have developed rapidly and are mainly distributed in southeastern and economically developed areas (Beijing, Shanghai, etc.), making up for the lack of alpine ski resorts in southern cities.

All of the ski areas in each of cities of China were included, and their spatial autocorrelation were analyzed by the global Moran's index and the Anselin local Moran's index (Figure 1c). The results suggested that city-level ski areas had a positive correlation ($I = 0.25$ and $Z = 19.2$), and the pattern was a clustered distribution. The high value areas were mainly concentrated in 3 areas: (1) cities near the Changbai Mountains in northeast China; (2) cities near Yanshan, Taihang and Lvliang Mountains in central-north China; (3) cities near the Tianshan Mountains in the northern Xinjiang Uygur Autonomous Region and Yinshan Mountains in central Inner Mongolia in northwest China. These results are consistent with previous studies [41,44].

3.2. Spatial Distributions of Natural Factors

3.2.1. Geographic Characteristics

China is a mountainous country with abundant mountain resources. The terrain is high in the west and low in the east and mainly has three terraces. As the first and highest terrace of China, the Qinghai-Tibet Plateau has an average elevation of over 4000 meters, and the elevation decreases gradually in the southeastern and eastern Tibetan Plateau. From the spatial pattern of the topographic slope and geomorphology shown in Figure 2, it can be seen that the mountain resources in China

were mainly distributed west of the Greater Khingan Range, Taihang Mountains, Wushan and Wuyi Mountains, which have a high relief and steep slopes. The eastern areas mainly consisted of plains, hills and low-relief mountains.

Figure 2. Spatial distribution of the slope (a) and geomorphology (b) with major ski areas.

There were notable differences in terrain features between the three types of ski areas. We analyzed the topographic and geomorphic features, including elevation, slope and landform types (Figures 2 and 3). The results showed that va-ski resorts and non-operational snow fields were mainly located in mountains with intermediate or high relief with an average slope of approximately 15–25 degrees, of which 6 resorts were located in the Changbai Mountains, 5 resorts were in the Yanshan Mountains, and the other 3 resorts were located in the Altay Mountains, Qinling Mountains and Taihang Mountains, respectively. The le-ski areas were mainly located in mountains with low relief or hills near suburbs, which were mainly distributed in the Changbai Mountains, Yanshan, Taihang Mountain, Tianshan, Qinling Mountains and Qilian Mountains. The average slope was approximately 5–15 degrees. In recent years, the ski tourism in China has continuously become more popular, and the number of ex-ski parks has increased rapidly. Such areas had low terrain requirements, and the average slope was less than 5 degrees, mainly distributed north of the Qinling Mountains and Huaihe

River and east of the Helan Mountains. Certain ex-ski parks were also located in the Qilian Mountains, Tianshan, Hengduan Mountains and Wuling Mountains.

Figure 3. Spatial distributions of va-ski resorts (a), le-ski areas (b) and ex-ski parks (c) in the major mountains in China.

3.2.2. Spatial Distribution of the Snow Cover

Snow cover is the most important factor affecting the stability and sustainability of ski resorts, and is also one of the main factors affecting the opening and closing dates and thus the economic benefits of ski areas [68–70]. The spatial distributions of the winter average and maximum snow depth are shown in Figure 4, and the duration of snow cover is shown in Figure 5. The results indicated that the snow cover was mainly distributed in high latitudes and high altitudes, including the Qinghai-Tibet Plateau, northeast China and Northern Xinjiang Uygur Autonomous Region, which formed the three main snow cover areas in China. However, compared with Western Europe and Western North America, which are affected by a temperate marine climate in winter, the snowfall and snow cover in China were insufficient; the maximum snow depth was 28 cm and the average snow depth was only 2 cm.

The average snow depth in the northern part of the Greater Khingan Range, the Lesser Khingan Range Mountains and the high altitude areas of the Altay Mountains in Xinjiang was greater than 15 cm. The average snow depth was approximately 5–10 cm in both the Changbai Mountains with Harbin as the center and the Tianshan-Altay Mountains with Urumqi as the center. In the Beijing-Tianjin-Hebei regions, for the hilly areas and the Taihang Mountains, the snow depth was less than 1 cm. The duration of snow cover ranged from 0 to 357 days. The average annual snow cover days in the high altitude areas of the Qinghai-Tibet Plateau and Northern Xinjiang were more than 200 days, while in northeast China (Heilongjiang, Jilin Province and northeastern Inner Mongolia Autonomous Region) and low-elevation mountains of northern Xinjiang Uygur Autonomous Region the average annual snow cover days were more than 100 days.

The 100 days-principle proposed by Witmer considered that sufficient snow resources were the guarantee for the stability of ski areas, which required 100 days of snow depth above 30 cm annually, and at least 7 of every 10 years [71]. This rule was widely used in subsequent studies [71–74]. However, the average snow depth of 591 Chinese alpine ski areas and non-operational snow fields varied from 0 cm to 18 cm in the winter, 69% of the ski areas had snow depths of less than 1 cm; 27.7% had snow depths of 1–10 cm, and only 3.3% had snow depths of more than 10 cm. The insufficient snow cover indicated that the natural snow resources in China hardly met this principle, and the ski areas were primarily dependent on artificial snow, which increased the cost of skiing. It was worth mentioning that the snow depth data we used is a passive microwave remote sensing data with a relatively coarse resolution (25km). The snow cover in mountain areas may be underestimated due to the impact of terrain on satellite sensors, resulting in lower snow depth in ski areas.

Figure 4. Cont.

Figure 4. Spatial pattern of the winter average snow depth (a) and winter maximum snow depth (b) with major ski areas in China.

Figure 5. Spatial pattern of average snow cover days with major ski areas in China.

3.2.3. Spatial Distribution Characteristics of the Climate

Global warming is the biggest challenge for alpine ski tourism. The spatial distributions of the winter average temperature and precipitation (Figure 6) were analyzed in this study to investigate the climatic conditions in China's ski industry. The results showed that the spatial difference of the average temperature from November to March in China was very large. The minimum temperature was -24°C in north of the Greater Khingan Range, and the highest temperature was 21°C in Hainan province and surrounding areas, with the regional maximum temperature difference up to 45°C . The average precipitation from November to March in China was small, and the maximum precipitation was only 119 mm, which was influenced by the cold Siberian High. The precipitation is mainly distributed in southeastern China, the southern margin of the Qinghai-Tibet Plateau, northern Xinjiang and east of northeast China.

Temperature and precipitation have strong spatial heterogeneity. In southeastern China, it is warm and humid, with temperatures above 5°C and most of the precipitation occurs in the winter;

only 10% of alpine ski areas were located in southeastern China and all of them were ex-ski parks. Approximately 56% of alpine ski areas were located in regions with an average temperature in the winter below 0 °C, of which included 86% of va-ski resorts and le-ski areas and 49.8% of ex-ski parks. Approximately 34% of alpine ski areas were approximately 0–5 °C, of which included 14% of va-ski resorts and le-ski areas and 36.4% of ex-ski parks.

Figure 6. Spatial pattern of the annual winter mean temperature (a) and precipitation (b) with major ski areas in China.

3.3. Spatial Distributions of Social Factors

3.3.1. Social Economic Factors and Population

In addition to the topography and climate, ski resorts largely depend on the number of consumers who are relatively wealthy. Therefore, the spatial distribution characteristics of the GDP and population density in 2010 were also analyzed in this study (Figure 7). The ski areas were in accordance with social economic factors and were mainly distributed in high value areas of the GDP and population. The eastern side of the Hu Huanyong Line, an important divide of population geography in China, contained 81.7% of the alpine ski areas while only 18.3% were distributed on the western side.

The eastern economic zone, as the most populous area with the highest per capita income in China, had 36% of the alpine ski areas and showed a decreasing distribution trend from north to south. The ski areas in the eastern economic zone were mainly concentrated in the Bohai Rim, including 4 va-ski resorts, 34 le-ski areas and 171 ex-ski parks. The central economic zone represents a sub-region of the Chinese population and GDP, in which 237 alpine ski areas (40%) were located. The ski areas in this region were densely distributed in northeast China (Heilongjiang, Jilin Province and Eastern Inner Mongolia Autonomous Region) and the Central Plains (Henan, Shanxi Province and Western Inner Mongolia Autonomous Region); these two regions accounted for 49 and 43% of the total ski areas in the central economic zone, respectively. Va-ski resorts and le-ski areas were mainly located in northeast China, and ex-ski parks were mainly located in the Central Plains. The western economic zone is the economic zone with the largest area, smallest population and lowest per capita GDP, and has widespread mountains, the Gobies and deserts. There were 143 alpine ski areas, of which 115 were ex-ski parks. The distribution of ex-ski parks was consistent with the economic development pattern, and they were mainly located in the Northern Tianshan Economic Belt, Hexi Corridor Economic Belt, Guanzhong-Tianshui Economic Zone and Chengdu-Chongqing Economic Zone.

Figure 7. Spatial pattern of the gross domestic product (a) and population density (b) in 2010 with major ski areas in China.

3.3.2. Traffic Accessibility

Accessibility is an important factor affecting the development of ski areas. Based on GIS spatial analysis technology, the spatial pattern of accessibility surfaces was calculated with provincial capitals and cities as nodes (shown in Figure 8). The accessibility presented distinct spatial differences with a decreasing trend from southeast to northwest China. The provincial capitals in the eastern coastal area had developed a transportation network and formed a core-periphery pattern with cities as cores. The traffic accessibility in northeast China and the Central Plains came second, while accessibility in northwest China was poor. The aforementioned traffic accessibilities were shown as corridor aggregated distributions along main road lines.

Approximately 55% of the alpine ski areas were located in regions within 2 h of the provincial capitals, and most were ex-ski parks and le-ski areas. The visitors in this region mainly came from the provincial capital and surrounding areas, which indicated that economic and traffic factors were probably the most important factors for ski area development. Thirty percent of the ski areas were in regions with an accessibility of approximately 3–4 h. The visitors of ex-ski parks and le-ski areas in this region mainly came from surrounding cities rather than the capitals because they lived much closer to cities, with an accessibility of 2 h (accounting for 95%). However, almost all va-ski resorts were distributed in mountains within approximately 3–4 h away from capitals due to the limitation of natural conditions (topography and climate, etc.). Accessibilities were not considered as the most important factors in the siting of va-ski resorts.

Figure 8. Spatial pattern of the accessibility with provincial capitals (a) and cities (b) as nodes in China.

3.4. Spatial Autocorrelation Analysis of Natural and Social Factors in Cities

We also analyzed the spatial autocorrelations of natural factors (terrain, climate and snow cover) and social factors (GDP and population density) (Figure 9). All these factors had a clustered distribution with a positive value of Index. The Moran's index of the average slope and the maximum relief of mountains in cities were 0.39 and 0.28, respectively. The high values of LISA were clustered in the Hengduan Mountains of the southeastern Tibetan Plateau and the Wuyi Mountains, while the low values were in the Northeast Plain and the North China Plain. The indexes of snow depth and snow cover days were 0.23 and 0.45, respectively. The high values of snow depth were mainly distributed in northeast China and eastern Inner Mongolia, while the high values of snow cover days were in northeast China, northern Xinjiang and southeastern Tibet. The Moran's index of the temperature and precipitation were 0.59 and 0.77, respectively, and the high values were concentrated in southeastern China, and the low values were in northeastern or northwestern China. Meanwhile, high values of the GDP and population density occurred in the eastern coastal cities and Chengdu-Chongqing areas.

Figure 9. The Anselin local Moran's index of multiple factors of cities in China.

The results of the spatial autocorrelation analysis of ski areas and their influence factors showed that there were differences among the driving factors of the three major ski industry zones in China: the ski industry centered on the Beijing-Tianjin-Hebei urban agglomeration were mainly driven by social economic factors, and a favorable location advantage was the prerequisite for the steady development of the ski industry. At the same time, this region is located in the hinterland of the Yanshan and Taihang Mountains, and suitable topographic and climatic conditions enabled the rapid development of the ski industry. The ski industries centered on the Harbin-Changchun urban agglomeration were mainly driven by favorable natural factors. For instance, the Changbai Mountains provided suitable topographic conditions, and high latitude offered low temperatures. Due to the monsoon climate, these areas are rich in ice and snow cover resources. This area was the earliest to use to develop the ice and snow tourism and ski industry in China, and va-ski resorts were mostly

located here. Because of the excellent ski conditions and snow resources, the ski resorts in this area were ideal places for winter skiing games; the ski industry centered on the urban agglomeration of the northern Tianshan Mountains were rich in snowfall and had a long duration (averaged 117 days per year) of snow cover and higher quality snow properties. However, the location disadvantage and distribution of the population density and GDP were the major limiting factors of ski industry development. Compared with the other two ski industry agglomeration areas, the ski industry in this area started late but developed rapidly, and most skiers were limited within the province. The area has great potential for future development because of its rich resources, high-quality snow properties and unique snow-related culture.

4. Discussion

4.1. Characteristics of Different Type of Ski Areas

The influence of the Beijing-Zhangjiakou Winter Olympic Games prompted a rapid development of the ski industry in China. However, ski areas are still small in scale and contain insufficient infrastructure, although the number is increasing continuously. Va-ski resorts that can be compared with international ski resorts accounted for only 2%, while le-ski areas and ex-ski parks accounted for 15% and 83%, respectively, of the total number of ski areas. Each type of ski areas has its own development modes. Understanding their characteristics and shortcoming are of significance to the sustainable development of ski industry.

Ex-ski parks are usually designed for beginners with few ski runs and only one or a few magic carpets. The lower allocation demand greatly reduces their cost, which makes skiing an affordable form of entertainment for ordinary people and quickly meets the increasing market demand. However, the siting of ski areas and the design of ski trails often lacks rational planning due to low requirements of terrain and snow quality. There are many ex-ski parks concentrated in regions with significant location advantages, resulting in intense competition for profits that is not beneficial to long-term development. At the same time, most ex-ski parks are not equipped with a melt-water recovery system and are likely to cause soil erosion and ecosystem degeneration in the region. Moreover, ski pistes are always occupied by unsupervised beginners, which not only creates a bad learning experience, but also the security of skiers is compromised. Le-ski areas are medium-sized, mainly distributed around cities and the target customers are local residents. It is an ideal place to cultivate people's interests in skiing because of better ski runs condition and favorable location advantages. However, the number of advanced pistes and lifts are relatively small. The phenomenon of short skiing time and long queuing time of cable cars often occurs during the peak period of skiing. The ski season length is relatively short and the quality of ski runs is poor at the end of the snow season because most le-ski areas are located in the regions with sub-optimal climate and topographic conditions. And the other common problems for le-ski areas are the simplification of development mode, unreasonable competition in high-quality areas of resources and the lack of skiing training areas for children.

In contrast, the number of va-ski resorts is much smaller and they are mainly located in northeast China and north China. The former, as the earliest region to develop modern skiing, contains most of the va-ski resorts, such as Yabuli, Beidahu, Wanke Songhua Lake and Wanda Changbaishan ski resorts. Suitable terrain and snow conditions, unique folk culture and advanced facilities result in these va-ski resorts being comparable to modern resorts in Europe and North America. However, extreme weather conditions, such as low temperatures and strong winds, often occur here, which not only affects the normal operation of ski areas but also provides poor skiing comfort to the skiers. At the same time, the local ski industry has a single tourism mode, and the surrounding towns have a low economic level and have not yet developed ice and snow tourism products reflecting local characteristics. The inconvenient traffic accessibility also increases the cost to ski visitors from developed cities. Va-ski resorts in North China are mainly concentrated in Chongli, a newly emerging ski destination in recent years and located in Zhangjiakou, Hebei Province. There are 4 major va-ski resorts (Wanlong, Genting

Resort Secret Garden, Thaiwoo and Fulong ski resorts) in the area, only 250 km away from Beijing. Situated at the intersection of the Beijing-Tianjin-Hebei and Shanxi-Hebei-Mongolia economic circles could be considered as an advantage of Chongli, which resulted in the area developing rapidly and becoming a tourism industry cluster area. However, the number and length of ski runs in these ski resorts are insufficient to meet the requirements of ski enthusiasts, and the cost is very high due to their dependence on artificial snow. Competition caused by the existence of several va-ski resorts in the region is not conducive to the development of the ski industry but also has a major impact on the local ecological environment.

4.2. Spatial pattern of Ski Areas and Its Driving Factors

Compared with previous studies [42–44], this work is the first to analyze the spatial pattern and driving factors of ski areas based on spatial autocorrelation theory. This approach is effective and visual method to elucidate the geospatial pattern and explore the driving factors. The results indicated that the locations of ski areas in China are mainly concentrated in three core areas: Beijing-Tianjin-Hebei urban agglomeration, Harbin-Changchun urban agglomeration and the northern Tianshan Mountains urban agglomeration. The first core area is governed by socio-economic factors. The larger population density and higher per capita income in the area were the foundation of the rapid development of the local ski industry. The second and third core areas were influenced by natural factors. The favorable climatic conditions and snow qualities of powder snow guaranteed the development of high-quality va-ski resorts.

The heterogeneity in the spatial distribution of natural and socio-economic resources might be the fundamental reason for the formation of this pattern. Mountainous resources, climate resources and snow resources supporting the development of the ski industry are mainly concentrated west of the Hu Huanyong Line, including the northeast, northwest and Qinghai-Tibet Plateau areas, while population, social economic and traffic factors promoted the development of the ski industry east of the Hu line.

4.3. Challenges of Healthy Development of Ski Industry

At present, skiing is a form of entertainment for most people rather than a sport that requires repeated practice. There is no skiing culture and most skiers do not ski more than once per season. Therefore, the stable and sustainable development still faces many challenges. As previous studies have indicated global warming would have a greater impact on small-scale and lower altitude resorts [7,31,33,75,76], which implies that China's ski industry in the future may suffer a greater risk than those in other regions of the world. Undoubtedly, this risk will be exacerbated if unreasonable siting, single operation modes and fierce regional competition conditions do not improve. With the international skiing boom shifting to Asia, China, with an emerging ski industry, will be one of the countries with the greatest potential for future development. A major challenge facing the ski industry in China is the mismatch between resources and markets. It is worth considering rational planning of the pattern of the Chinese ski industry and developing a ski culture with Chinese characteristics, while retaining domestic skiers and attracting foreign skiers. Moreover, the traditional alpine ski teaching methods are not suitable for the current Chinese consumption patterns and talent training is an urgent problem to be addressed to promote the stable development of the ski industry.

4.4. Development Strategy

The development of the ski industry in China is still in its infancy. Therefore, the main policy orientation in the future should be to enable the transformation and upgrade of the infrastructure and construction of ski areas, to develop ski industry alliances and to promote the cluster development of ski areas. The government should promulgate relevant policies to promote the rational development and utilization of mountain and snow resources in western China, utilize tourism resources as a point of contact, build a ski industry with Chinese characteristics, seize the huge market potential in China, and thus drive the economic growth of western China. For eastern China, the different grades of

ski industry agglomeration zones should be built. For example, high-quality va-ski resorts should be developed in Northeast China, while paying attention to the export of talent; va-ski resorts and le-ski areas should be considered in North China, focusing on cultivating people's interest in skiing. In Central China, the development of le-ski areas and ex-ski parks are crucial to stimulate the public enthusiasm for skiing by experiencing the fun of skiing. At the same time, indoor snow centers should be established in South China.

Meanwhile, according to the characteristics of different types of ski areas, the possible development strategies are given as follows:

- (1) Government departments should undertake a full investigation into the natural resources and socio-economic conditions available and scientifically evaluate the development feasibility of the ski industry in various regions;
- (2) Reasonable plans should be formulated in order to effectively allocate and integrate local ski resources. The natural and ecological environment should be protected, while developing economy. Moreover, the standards for infrastructure, services and safety of different type of ski areas should be drafted, the approval standards of new ski areas should be strictly controlled and the infrastructure construction of existing ex-ski parks should be improved.
- (3) Different types of ski areas should have different development emphases. For example, Va-ski resorts should focus on international development, actively host various international competitions and create development modes with Chinese characteristics so as to attract international ski enthusiasts and enhance the international competitiveness of China's ski industry. Moreover, the main ways for the healthy and stable development of Va-ski resorts involve diversified tourism, a four-season business model implementation and a unified ski system by which one ticket allows visitors to ski freely in multiple ski resorts in the region. Le-ski areas should pay attention to domestic markets and focus on cultivating Chinese skiing hobbies. Le-ski areas should cooperate with local education departments to actively carry out Youth Winter Camp and skiing skill training, so as to stimulate the public enthusiasm for skiing and foster a skiing culture in China. In contrast, Ex-ski parks should take skiing as a form of entertainment and provide winter recreation for the public by providing places to ski and other facilities such as snowmobiles and ski circles. Meanwhile, the quality and service of ex-ski parks can be improved by limiting the flow of hourly skiers.

Additionally, although the goal of having 300 million Chinese participants in winter sports has promoted the development of the ski industry, there is still great uncertainty about how to achieve it. There is no major skiing culture in China, so we should pay attention to the cultivation of teenagers interested in skiing. Winter camps for skiing should be actively developed and the cost of youth training should be reduced through enterprise relief and state subsidies.

However, due to the limitation of available data of ski areas, the selection of indicators for scientific classification still needs further improvement. And the snow cover in mountains may be underestimated because of the coarse spatial resolution of snow depth data. Climate factors such as temperature and precipitation are obtained using spatial interpolation, which will lead to some deviations from the actual data. Therefore, quantitative research on spatial pattern of the ski industry based on high spatial and temporal resolution data still needs to be strengthened.

5. Conclusions

This study collected the location and basic information of ski areas, as well as the natural and socio-economics factors affecting the ski industry. A new classification criteria was established based on existing standards and actual situation of ski areas. The theory and method of spatial autocorrelation were used to analyze the spatial pattern and driving factors of ski areas. By systematically analyzing the characteristics of different types of ski areas and the driving factors of spatial pattern, feasible

strategies for the healthy and sustainable development of the Chinese ski industry are put forward. Conclusions of the research are as follows:

- (1) Data from 620 ski areas were collected until 2017, including 589 alpine ski areas, 29 indoor snow centers and 2 non-operational snow fields for backcountry skiing. The alpine ski areas can also be divided into three types: ski resorts for vacationing (va-ski resorts), ski areas for learning (le-ski areas) and ski parks to experience skiing (ex-ski parks), with proportions of 2.1%, 15.4% and 82.5%, respectively. The results showed that the Chinese ski industry has been dominated by small- and medium-sized ski areas. Unreasonable planning and fierce competition in regions with abundant resources are the main factors that restrict the healthy development of ski industry;
- (2) The results of NNI index and kernel density estimation indicated that the spatial pattern of ski areas was clustered distribution. Ski areas were found to be mainly concentrated in 3 regions: the Beijing-centered Yanshan-Taihang Mountains and Shandong Hill areas, the Harbin-centered Changbai Mountain areas and the Urumqi-centered Tianshan-Altaï Mountain areas.
- (3) The spatial autocorrelation analysis of ski areas and their influence factors showed that the ski industry centered on the Beijing-Tianjin-Hebei urban agglomeration was mainly driven by social economic factors, and the ski industries centered on the Harbin-Changchun urban agglomeration and the northern Tianshan Mountains urban agglomeration were driven by favorable natural factors;
- (4) Government departments should strengthen supervision and advocate industrial alliances. The reasonable industrial positioning for different typed ski areas should be formulated according to their respective characteristics. Natural resources and socio-economy should be fully investigated so as to establish healthy development modes.

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References

1. Formenti, F.; Ardigo, L.P.; Minetti, A.E. Human Locomotion on Snow: Determinants of Economy and Speed of Skiing across the Ages. *Proc. Biol. Sci.* **2005**, *272*, 1561–1569. [[CrossRef](#)] [[PubMed](#)]
2. Shan, Z.; Wang, B. *The Original Place of Skiing—Altay Prefecture of Xinjiang, China*; People's Sports Publishing House of China: Beijing, China, 2011.
3. Moser, P.; Moser, W. Reflections on the MAB-6 Obergurgl Project and Tourism in an Alpine Environment. *Mt. Res. Dev.* **1986**, *6*, 101–118. [[CrossRef](#)]
4. Price, M.F. Patterns of the Development of Tourism in Mountain Environments. *GeoJournal* **1992**, *27*, 87–96. [[CrossRef](#)]
5. Barbier, B. Problems of the French Winter Sport Resorts. *Tour. Recreat. Res.* **1993**, *18*, 5–11. [[CrossRef](#)]
6. Elsasser, H.; Bürki, R. Climate Change as a Threat to Tourism in the Alps. *Clim. Res.* **2002**, *20*, 253–257. [[CrossRef](#)]
7. Lasanta, T.; Laguna, M.; Vicente-Serrano, S.M. Do Tourism-based Ski Resorts Contribute to the Homogeneous Development of the Mediterranean Mountains? A Case Study in the Central Spanish Pyrenees. *Tour. Manag.* **2007**, *28*, 1326–1339. [[CrossRef](#)]
8. Vedenin, N.A.; Odesser, S.V.; Zhao, B. Recreational Utilization in Mountain Areas. *Prog. Geogr.* **1990**, *9*, 46–51.

9. Alexandris, K.; Kouthouris, C.; Meligdis, A. Increasing Customers' Loyalty in a Skiing Resort: The Contribution of Place Attachment and Service Quality. *Int. J. Contemp. Hosp. Manag.* **2006**, *18*, 414–425. [[CrossRef](#)]
10. Flagestad, A.; Hope, C.A. Strategic Success in Winter Sports Destinations: A Sustainable Value Creation Perspective. *Tour. Manag.* **2001**, *22*, 445–461. [[CrossRef](#)]
11. Gilbert, D.; Hudson, S. Tourism Demand Constraints: A Skiing Participation. *Ann. Tour. Res.* **2000**, *27*, 906–925. [[CrossRef](#)]
12. Hudson, S.; Ritchie, B.; Timur, S. Measuring destination competitiveness: An empirical study of Canadian ski resorts. *Tour. Hosp. Plan. Dev.* **2004**, *1*, 79–94. [[CrossRef](#)]
13. Hudson, S.; Shephard, G.W.H. Measuring Service Quality at Tourist Destinations: An Application of Importance-performance Analysis to an Alpine Ski Resort. *J. Travel Tour. Mark.* **1998**, *7*, 61–77. [[CrossRef](#)]
14. Berg, H.E.; Eiken, O. Muscle Control in Elite Alpine Skiing. *Med. Sci. Sports Exerc.* **1999**, *31*, 1065–1067. [[CrossRef](#)] [[PubMed](#)]
15. Bouter, L.M.; Knipschild, P.G.; Volovics, A. Binding Function in Relation to Injury Risk in Downhill Skiing. *Am. J. Sports Med.* **1989**, *17*, 226–233. [[CrossRef](#)] [[PubMed](#)]
16. Burtscher, M.; Gatterer, H.; Flatz, M.; Sommersacher, R.; Woldrich, T.; Ruedl, G.; Hotter, B.; Lee, A.; Nachbauer, W. Effects of Modern Ski Equipment on the Overall Injury Rate and the Pattern of Injury Location in Alpine Skiing. *Clin. J. Sport Med. Off. J. Can. Acad. Sport Med.* **2008**, *18*, 355–357. [[CrossRef](#)] [[PubMed](#)]
17. Ettlinger, C.F.; Johnson, R.J.; Shealy, J.E. *Functional and Release Characteristics of Alpine Ski Equipment*; ASTM International: West Conshohocken, PA, USA, 2006.
18. Hunter, R.E. Skiing Injuries. *Am. J. Sports Med.* **1976**, *27*, 381–389. [[CrossRef](#)] [[PubMed](#)]
19. Johnson, R.J.; Ettlinger, C.F.; Campbell, R.J.; Pope, M.H. Trends in Skiing Injuries: Analysis of a 6-year Study (1972 to 1978). *Am. J. Sports Med.* **1980**, *8*, 106–113. [[CrossRef](#)] [[PubMed](#)]
20. Koehle, M.S.; Lloyd-Smith, R.; Taunton, J.E. Alpine Ski Injuries and Their Prevention. *Sports Med.* **2002**, *32*, 785–793. [[CrossRef](#)] [[PubMed](#)]
21. Grímsdóttir, H. *Avalanche Risk Management in Backcountry Skiing Operations*; The University of British Columbia: Vancouver, BC, Canada, 2004.
22. Grímsdóttir, H.; Mcclung, D. Avalanche Risk During Backcountry Skiing—An Analysis of Risk Factors. *Nat. Hazards* **2006**, *39*, 127–153. [[CrossRef](#)]
23. Jamieson, B.; Schweizer, J.; Shea, C. Simple Calculations of Avalanche Risk for Backcountry Skiing. In Proceedings of the International Snow Science Workshop Davos 2009, Davos, Switzerland, 27 September–2 October 2009.
24. Brown, R.D.; Mote, P.W. The Response of Northern Hemisphere Snow Cover to a Changing Climate. *J. Clim.* **2010**, *22*, 2124–2145. [[CrossRef](#)]
25. Diffenbaugh, N.S.; Scherer, M.; Ashfaq, M. Response of Snow-dependent Hydrologic Extremes to Continued Global Warming. *Nat. Clim. Chang.* **2013**, *3*, 379–384. [[CrossRef](#)] [[PubMed](#)]
26. Tegart, W.J.; Sheldon, G.W.; Griffiths, D.C. *Climate Change: The IPCC Impacts Assessment*; Australian Government Publishing Service: Canberra, Australia, 1990.
27. Demiroglu, O.C.; Kučerová, J.; Ozcelebi, O. Snow Reliability and Climate Elasticity: Case of a Slovak Ski Resort. *Tour. Rev.* **2015**, *70*, 1–12. [[CrossRef](#)]
28. Gilaberte-Búrdalo, M.; López-Moreno, J.; Morán-Tejeda, E.; Jerez, S.; Alonso-González, E.; López-Martín, F.; Pino-Otín, M. Assessment of Ski Condition Reliability in the Spanish and Andorran Pyrenees for the Second Half of the 20th Century. *Appl. Geogr.* **2017**, *79*, 127–142. [[CrossRef](#)]
29. Heo, I.; Lee, S. The Impact of Climate Changes on Ski Industries in South Korea. *J. Korean Geogr. Soc.* **2008**, *43*, 715–727.
30. Kim, S.; Park, C.; Park, J.; Lee, D. Estimating Effects of Climate Change on Ski Industry—The Case of Ski Resorts in South Korea. *J. Environ. Impact Assess.* **2015**, *24*, 432–443. [[CrossRef](#)]
31. Rutt, M.; Scott, D.; Johnson, P.; Pons, M.; Steiger, R.; Vilella, M. Using Ski Industry Response to Climatic Variability to Assess Climate Change Risk: An Analogue Study in Eastern Canada. *Tour. Manag.* **2017**, *58*, 196–204. [[CrossRef](#)]
32. Wobus, C.; Small, E.E.; Hosterman, H.; Mills, D.; Stein, J.; Rissing, M.; Jones, R.; Duckworth, M.; Hall, R.; Kolian, M. Projected Climate Change Impacts on Skiing and Snowmobiling: A Case Study of the United States. *Glob. Environ. Chang.* **2017**, *45*, 1–14. [[CrossRef](#)]

33. Steiger, R.; Mayer, M. Snowmaking and Climate Change: Future Options for Snow Production in Tyrolean Ski Resorts. *Mt. Res. Dev.* **2008**, *28*, 292–298. [CrossRef]
34. Wang, Q. Thoughts on Promoting the Industrialization of Skiing in China. *China Winter Sports* **1996**, *3*, 28–30.
35. Zhang, G. *Research on the Issues in the Development of Skiing Industry of China*; Northeast Forestry University: Harbin, China, 2008.
36. Sun, C.; Wu, B.; Wei, Q.; Zhang, H. *Annual Report on Development of Ski Industry in China*; Social Sciences Academic Press (China): Beijing, China, 2017.
37. Han, J.; Han, D. Comparative Study of Ski Tourism at Home and Abroad. *Hum. Geogr.* **2001**, *16*, 26–30.
38. Han, J.; Han, D. The Discussion of Several Problems of Ski Tourism in China. *Econ. Geogr.* **2001**, *21*, 116–119.
39. Gu, H. *A Research on the Sustainable Development of Skiing Sports in Our Country, China*; Northeast Normal University: Changchun, China, 2010.
40. Li, Y.; Zhao, M.; Guo, P.; Zheng, J.; Li, Z.; Li, F.; Shi, Y.; Dong, S. Comprehensive Evaluation of Ski Resort Development Conditions in Northern China. *Chin. Geogr. Sci.* **2016**, *26*, 1–9. [CrossRef]
41. Li, X. Analysis on the Sustainable Development of Three Core Areas of Skiing in China. *J. Beijing Sport Univ.* **2017**, *40*, 9–16.
42. Liu, J.; Liu, A.; Chen, T. Influencing Factors and Countermeasures of Skiing Resort Development Distribution with Inner Mongolia Municipality's Skiing Tourism Development as an Example. *Prog. Geogr.* **2005**, *24*, 105–112.
43. Ming, J.; Meng, M.; Chen, X.; Xu, J. Research of the Rational Layout of China Skiing Resorts. *China Winter Sports* **2009**, *31*, 88–93.
44. Wang, S.; Xu, X.; Deng, J.; Zhou, L. Chinese Skiing-tourism Destination: Spatial Patterns, Existing Problems and Development Countermeasures. *J. Glaciol. Geocryol.* **2017**, *39*, 902–909.
45. Ye, H.; Zhang, Y. Research on Sustainable Development of Chinese Skiing Tourism Industry. *China Winter Sports* **2015**, *37*, 88–92.
46. Qian, H. *Spatial and Temporal Variation of Snow Cover in Beijing and Zhangjiakou Region and its Potential Impacts on the 2022 Beijing-Zhangjiakou Olympic Winter Games*; Nanjing University: Nanjing, China, 2017.
47. Song, S.; Zhang, S.; Wang, T.; Meng, J.; Zhou, Y.; Zhang, H. Balancing Conservation and Development in Winter Olympic Construction: Evidence from a Multi-Scale Ecological Suitability Assessment. *Sci. Rep.* **2018**, *8*, 14083. [CrossRef]
48. Xiao, W.; Xiao, C.; Guo, X.; Ma, L. Winter and Spring Snow Cover Features in Beijing-Zhangjiakou Region. *J. Glaciol. Geocryol.* **2016**, *38*, 584–595.
49. Yao, X. The SWOT Analysis of Development Countermeasure of Ice-snow Sports Resources in Beijing and Zhangjiakou Areas. *J. Harbin Inst. Phys. Educ.* **2018**, *36*, 15–21.
50. Yang, J.; Yang, R.; Sun, J.; Huang, T.; Ge, Q. The Spatial Differentiation of the Suitability of Ice-Snow Tourist Destinations Based on a Comprehensive Evaluation Model in China. *Sustainability* **2017**, *9*, 774. [CrossRef]
51. Cai, W.; Di, H.; Liu, X. Estimation of the Spatial Suitability of Winter Tourism Destinations Based on Copula Functions. *Int. J. Environ. Res. Public Health* **2019**, *16*, 186. [CrossRef] [PubMed]
52. Cheng, Z. The Comprehensive Evaluation of Suitability of Ice-snow Tourism base in China. *Resour. Sci.* **2016**, *38*, 2233–2243.
53. Che, T.; Li, X.; Jin, R.; Armstrong, R.; Zhang, T. Snow Depth Derived from Passive Microwave Remote-sensing Data in China. *Ann. Glaciol.* **2008**, *49*, 145–154. [CrossRef]
54. Wang, Y.; Huang, X.; Liang, H.; Sun, Y.; Feng, Q.; Liang, T. Tracking Snow Variations in the Northern Hemisphere Using Multi-Source Remote Sensing Data (2000–2015). *Remote Sens.* **2018**, *10*, 136. [CrossRef]
55. Cao, X.; Li, T.; Yang, W.; Huang, X.; Yin, J.; Liu, Y.; Liang, F.; Wang, W.; Wang, M.; Chen, H.; et al. Accessibility and Urban Spatial Connections of Cities in the Silk Road Economic Belt based on Land Transportation. *Process Geogr.* **2015**, *34*, 657–664.
56. Chinese Ski Association. *Standards for Management of Ski Resorts in China*; People's Sports Press: Beijing, China, 2017.
57. Bureau of Tourism of the People's Republic of China. *Quality Classification of Tourist Ski Resorts*; Bureau of Tourism of the People's Republic of China: Beijing, China, 2014. Available online: <http://tour.rednet.cn/c/2015/01/05/3567360.htm> (accessed on 26 December 2014).
58. Wu, B.; Wei, Q. *2017 China Ski Industry White Book*. Available online: <https://www.vanat.ch/publications.shtml> (accessed on 15 January 2018).

59. Vanat, L. *International Report on Snow & Mountain Tourism: Overview of the Key Industry Figures for Ski Resorts*. Available online: <http://www.vanat.ch/RM-world-report-2018.pdf> (accessed on 22 May 2018).
60. Wang, J.; Liao, Y.; Liu, X. *Spatial Data Analysis*; Science Press: Beijing, China, 2010.
61. Getis, A.; Ord, J.K. The Analysis of Spatial Association by Use of Distance Statistics. *Geogr. Anal.* **1992**, *24*, 189–206. [[CrossRef](#)]
62. Cliff, A.D.; Ord, J.K. *Spatial Autocorrelation*; Pion: London, UK, 1973.
63. Fu, W.; Zhao, K.; Zhang, C.; Tunney, H. Using Moran's I and Geostatistics to Identify Spatial Patterns of Soil Nutrients in Two Different Long-term Phosphorus-application Plots. *J. Plant Nutr. Soil Sci.* **2011**, *174*, 785–798. [[CrossRef](#)]
64. Moran, P.A.P. Notes on Continuous Stochastic Phenomena. *Biometrika* **1950**, *37*, 17–23. [[CrossRef](#)]
65. Zhang, S.; Zhang, K. Comparison between General Moran's Index and Getis-Ord General G of Spatial Autocorrelation. *Acta Sci. Nat. Univ. Sunyatseni* **2007**, *46*, 93–97.
66. Anselin, L. Local Indicators of Spatial Association—LISA. *Geogr. Anal.* **1995**, *27*, 93–115. [[CrossRef](#)]
67. Zhang, C.; Luo, L.; Xu, W.; Ledwith, V. Use of Local Moran's I and GIS to Identify Pollution Hotspots of Pb in Urban Soils of Galway, Ireland. *Sci. Total Environ.* **2008**, *398*, 212–221. [[CrossRef](#)]
68. Elsasser, H.; Messerli, P. The Vulnerability of the Snow Industry in the Swiss Alps. *Mt. Res. Dev.* **2001**, *21*, 335–339. [[CrossRef](#)]
69. Fischer, A.; Olefs, M.; Abermann, J. Glaciers, Snow and Ski Tourism in Austria's Changing Climate. *Ann. Glaciol.* **2011**, *52*, 89–96. [[CrossRef](#)]
70. Ponspons, M.; Johnson, P.A.; Rosascasals, M.; Sureda, B.; Jover, È. Modeling Climate Change Effects on Winter Ski Tourism in Andorra. *Clim. Res.* **2012**, *54*, 197–207. [[CrossRef](#)]
71. Witmer, U. *Recording, Processing and Mapping of Snow Data in Switzerland*; University of Bern: Bern, Switzerland, 1986.
72. Demiroglu, O.C.; Turp, M.T.; Ozturk, T.; Kurnaz, M.L. Impact of Climate Change on Natural Snow Reliability, Snowmaking Capacities, and Wind Conditions of Ski Resorts in Northeast Turkey: A Dynamical Downscaling Approach. *Atmosphere* **2016**, *7*, 52. [[CrossRef](#)]
73. Scott, D.; Mcboyle, G.; Mills, B. Climate Change and the Skiing Industry in Southern Ontario (Canada): Exploring the Importance of Snowmaking as a Technical Adaptation. *Clim. Res.* **2003**, *23*, 171–181. [[CrossRef](#)]
74. Tepfenhart, M.; Mauser, W.; Siebel, F. The Impacts of Climate Change on Ski Resorts and Tourist Traffic. *Ecol. Lett.* **2007**, *9*, 228–241.
75. Breiling, M.; Charamza, P. The Impact of Global Warming on Winter Tourism and Skiing: A Regionalised Model for Austrian Snow Conditions. *Reg. Environ. Chang.* **1999**, *1*, 4–14. [[CrossRef](#)]
76. Koenig, U.; Abegg, B. Impacts of Climate Change on Winter Tourism in the Swiss Alps. *J. Sustain. Tour.* **1997**, *5*, 46–58. [[CrossRef](#)]

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