

## Article

# A Model-Based Assessment for the Ability of National Nature Reserves to Conserve the *Picea* Species in China under Predicted Climate Conditions

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**Abstract:** Climate change has a profound impact on the conservation and management of the *Picea* species, and establishing more nature reserves would be an effective way to conserve wild species in general. Based on a novel computational method using ecological niche modeling to predict the potential geographical distribution of species and a spatial decision support system, the planning process could predict the future distribution of the *Picea* species and thus select appropriate nature reserves. In this research, we utilized systematic conservation planning to define priority conservation areas for the *Picea* species in China according to future climate predictions. We hypothesized that: (1) the distribution of the *Picea* species could be changed under predicted climate conditions in China; (2) the current national nature reserves had sufficient capacity to conserve *Picea* species under predicted climate conditions in China; and (3) there were still deficiencies in the planned conservation for the *Picea* species based on predicted climate predictions in China. The results of a spatial analysis showed that the predicted climate would have an impact on the area of distribution of the *Picea* species. Current nature reserves have a strong potential to conserve the *Picea* species. However, the conservation of the *Picea* species in the existing nature reserves was not adequate. There were still many *Picea* specimens outside the reserve that would be threatened. This research systematically improved the research on the *Picea* species, and it also scientifically identified the suitable growth and conserved areas of the *Picea* species in China to provide an empirical basis for the conservation and management of the *Picea* species.

**Keywords:** climate change; conservation capability; nature reserves; *Picea* species; priority conservation areas; spatial decision



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## 1. Introduction

Species have been reacting to environmental changes by adapting, migrating [1], or even becoming extinct [2,3]. In the same way, conservation management has been highly affected by climate change [4]. Preserving endangered plant species in the face of climate change is both imperative and urgent [5]. However, the issue of integrating climate change into biodiversity conservation planning of endangered plant species is still a challenge [6].

*Picea* species, as common species in high-altitude areas [7], have been objects of study by several researchers [8,9]. Examples include the growth of *P. mariana* forests in northern Canada [10], and the cultivation of *P. abies* L. Karst in Slovakia under climate change [11]. However, previous studies have primarily focused on the research of a specific *Picea* species [8,12] or on the biological characteristics of the *Picea* species from a micro perspective [13]. There has been a lack of research on the macro-distribution pattern of the *Picea* species under the influence of climate change. However, there are substantial conservation values concerning the *Picea* species as a resource, specifically in China [14]. These species have a high economic value and show a strong adaptation capacity [15]. Moreover, they are also highly effective in conserving water [16]. The *Picea* species have

been relevant for the afforestation efforts in their distribution areas [17]. Some of these species show high tolerance to drought [18], including the severely endangered species *P. meyeri* [19]. The *Picea* species are an important dominant coniferous species in the temperate regions of north-central China [20]. The natural forests of the *Picea* species grow slowly [21]. China has the greatest amount of diversity within the *Picea* genus [17], holding about 19 different species, and could serve as the distribution center of plant material. Of the total of species that grow in China, 11 have been listed as endangered or in need of conservation (IUCN, 2021; NAEP and IBCAS, 1987; <http://www.iplant.cn> (accessed on 1 December 2021)) [22,23]. If the *Picea* species is not properly monitored and conserved, it could result in the extinction of a natural forest resource and, thus, damage biodiversity [24].

Previous studies have shown that nature reserves play an important role in conserving endangered plant species through in situ and ex situ conservation [25–27]. Establishing more nature reserves is a direct and effective way of biodiversity conservation [28]. Nature reserves refer to representative natural ecosystems and natural concentrated distribution areas of rare and endangered wild animals and plants [29]. These ones may also include areas designated by law for the special conservation and management of the land, body of water, or coastal regions where conserved species or objects, such as natural relics with special significance, are located [29]. National nature reserves have been effective for the conservation of biodiversity, the construction of ecological security barriers [30], the safety and stability of natural ecosystems [31], and improvements in the quality of ecological environments. The establishment of national nature reserves has been suggested as the most effective method by which to conserve rare and endangered wild plants [32].

Novel computational methods have been developed based on prediction algorithms that use ecological niche modeling to predict the potential geographical distribution of species [33]. Predicting future species distributions and selecting appropriate nature reserves requires the use of species distribution model (SDM) programs that are based on spatial analysis. Spatial decision support systems provide a framework for the integration and analysis of spatial, economic, technical, and other disproportionate data in the planning process. The flexible and effective spatial analysis does not rely on a single model or tool. Based on our research, data have been expressed more effectively using spatial decision-making. In this study, we used systematic conservation planning to define priority conservation areas (PCAs) for the *Picea* species in China under predicted climate conditions, and we tested the following three hypotheses: (1) the species distribution could change for the *Picea* species in China under predicted climate conditions; (2) the current national nature reserves had sufficient capacity to conserve the *Picea* species in China under predicted climate conditions; and (3) conservation deficiencies exist for the *Picea* species in China under predicted climate conditions.

## 2. Material and Methods

### 2.1. Data of Species, Climate and National Nature Reserves

The species within the *Picea* genus that were considered in this study are: *P. brachytyla*, *P. brachytyla* var. *comparata*, *P. likiangensis*, *P. likiangensis* var. *rubescens*, and *P. likiangensis* var. *linzhiensis*. Their wood has economic value and can be used as industrial raw materials. They are suitable as the main afforestation trees in plateau areas, and they are endemic to China as endangered conserved species. Due to the scattered wild resources of these *Picea* species and their variants, the quantity of goods they provide has been limited. From the perspective of production and marketing, the output of these five *Picea* species' wild products has been declining, and cultivated products have been increasing. Therefore, the cultivation of these five *Picea* species could still be the main source of commercial *Picea* species in the future. This fact provides an extra reason for reinforcing the conservation plans.

The MaxEnt model was used to predict the potential distribution areas of the studied species and discuss the environmental factors shaping their distribution patterns. The grid cells of the area in which *Picea* species appear were primarily obtained using the following

two methods: (1) Field survey data that were recorded from 2020 to 2021 using a handheld Global Positioning System (GPS) and (2) a variety of online databases, including the Global Biodiversity Information Facility (GBIF; [www.gbif.org](http://www.gbif.org) (accessed on 1 December 2021)), LIFEMAPPER ([www.lifemapper.com](http://www.lifemapper.com) (accessed on 1 December 2021)), and the Chinese Virtual Herbarium (CVH; [www.cvh.org.cn](http://www.cvh.org.cn) (accessed on 1 December 2021)). The number of grid cells indicated the size of area. A larger number of grid cells indicated a larger area. There were 775 sample data of the two species and the three varieties, of which 258 corresponded to *P. brachytyla*, 137 to *P. brachytyla* var. *comparata*, 187 to *P. likiangensis*, 141 to *P. likiangensis* var. *rubescens* and 52 to *P. likiangensis* var. *linzhiensis*.

Previous studies have focused on species classification [34,35], growth [36], tree ring records [37], somatic embryogenesis and plant regeneration, as well as the methods of intraspecific differentiation and expansion [38], the impact of the climate on species growth [39], the relationship between insect species [40], and their trait variation [41]. Thus far, there has been little research concerning *Picea* distribution and conservation.

Climate-related data were obtained from WorldClim (<https://worldclim.org/> (accessed on 1 December 2021)). The predicted climate scenarios involved three sets of predicted climate models (MIROC6, MIROC-ES2L, and MRI-ESM2-0) of Shared Socioeconomic Pathways (SSPs) (245 and 585) for 5-arc-min over 20-year periods (2081–2100). The ssp2-4.5 [42] is a moderate socioeconomic development pathway that has been updated based on an RCP4.5 scenario with a targeted radiative forcing of  $4.5 \text{ Wm}^{-2}$  at the end of twenty-first century; it is also referred to as an intermediate development pathway; while ssp5-8.5, updated from RCP8.5, is referred as a high development pathway. This one includes an emission scenario with targeted radiative forcing  $8.5 \text{ Wm}^{-2}$  at the end of the twenty-first century [43]. The ssp2-4.5 poses moderate challenges to mitigation and adaptation, and ssp5-8.5 poses high challenges to mitigation and low challenges to adaptation [44]. One of the main simulation sets applied by the climate model was the predicted climate scenario, in which the model was provided a common set of predicted greenhouse gases and other parameters for its predictions. Currently, scientists have developed a new set of emission scenarios driven by different socioeconomic assumptions, namely, SSPs, which includes ssp2-4.5 and ssp5-8.5. In addition, 5-arc-min represented spatial resolution or minutes of a degree of longitude and latitude. We use the data of the weighted average values of the three climate models of each *Picea* species under different scenarios as climate variables [45–47]. Eight climate variables with large contribution values in the MaxEnt model were used: Bio1 (annual mean temperature), Bio4 (temperature seasonality), Bio5 (max temperature of warmest month), Bio6 (min temperature of coldest month), Bio12 (annual precipitation), Bio13 (precipitation of wettest month), Bio14 (precipitation of driest month), and Bio15 (precipitation seasonality (coefficient of variation)).

By the end of 2019, China established 2750 nature reserves for conservation [48] (among these, there were 489 national nature reserves), covering a total area of approximately 147 million  $\text{km}^2$  and representing approximately 14.86% of the land area (<http://www.nrchina.org/> (accessed on 5 December 2021)). In this study, the data on China's national nature reserves were obtained from the Resource and Environmental Science and Data Center (<https://www.resdc.cn/Default.aspx> (accessed on 5 December 2021)). The data from the world database of conserved areas (WDPA) were used to identify the nature reserves (IUCN I–VI) in China that were suitable for further analysis. Finally, we conducted a cross-analysis between the results of SDM and the boundary of the reserve to obtain the distribution of *Picea* species in 250 nature reserves to evaluate the capacity of national nature reserves to conserve Chinese *Picea* species under predicted climate conditions.

## 2.2. Species Distribution Modeling (SDM)

MaxEnt (v.3.3.3; <http://www.cs.princeton.edu/~schapire/maxent/> (accessed on 15 December 2021)) was used to model the current and predicted distribution of *Picea* species [49]. All the pixels were regarded as possible distribution spaces of maximum entropy [50]. The probability of the occurrence of potential distribution of *Picea* species was interpreted as

habitat quality, and the distribution pixels of the *Picea* species records collected from the field surveys were treated as sample occurrences. MaxEnt cell values of 1 were the highest habitat quality scores, and values close to 0 were the lowest. MaxEnt was used to estimate the function of habitat quality with maximum entropy, and the model of geographic locations of *Picea* species was based on environmental variables. Furthermore, the potential areas of distribution were determined by comparison to the areas where the climate conditions of the research region were similar. Therefore, the computed results reflected the quality of habitat.

The GPS positions (longitude and latitude) were used for the grid cell inputs. Of these locations, 75% were used for model training, and 25% were used for testing. The maximum number of background grid cells was 10,000, and auto features were used. Other values were maintained as default. The jackknife test was used to analyze the importance of different environmental factors using MaxEnt. Receiver-operating characteristic (ROC) curves of each value of the prediction results were a potential threshold, and the corresponding sensitivity and specificity were then obtained by calculation. The precision of the model was evaluated by calculating the area under the ROC Curve (AUC). Higher AUC values indicated that there was a stronger relationship between the 19 bioclimatic variables [51]. This ensured better predictions of species distribution. The model was graded as follows: poor (AUC < 0.8), fair (0.8 < AUC < 0.9), good (0.9 < AUC < 0.95), and very good (0.95 < AUC < 1.0; [52]). The value range of the final potential distribution of *Picea* species from 0 to 1 was divided into five categories to denote potential habitat quality: highest (>0.8), high (0.6–0.8), good (0.4–0.6), moderate (0.2–0.4), and least (<0.2).

### 2.3. Systematic Conservation Planning

The details of Zonation software and its algorithm have been fully described in previous studies [53–56]. First, we planned to model priority conservation areas (PCAs) for the studied plant material using the conservation planning software Zonation (<http://cbig.it.helsinki.fi/software/> (accessed on 15 December 2021)). We used it to build the distribution map and provided the software with target PCAs with high-priority rankings for species-richness conservation. The highest PCAs of *Picea* species were confirmed by identifying the top-ranking cells after the Zonation computation [57]. We minimized the geographic distance between the potential habitats of five *Picea* species and varieties and then considered the influence of geographic distance when selecting potential sites for reserves. Using the original core-area cell removal rule, we set spatial priorities and computed the marginal loss of each cell, which we then used to determine if a conservation goal had been reached. The attainment of goals was determined based on a provided “conservation proportion” of distributions for all the species with high priority rankings [58]. The predicted habitat distribution maps of *Picea* species, as assessed by MaxEnt for each pixel (namely, the input layers for Zonation), were used in the Zonation algorithm to simulate PCAs. Five *Picea* species and varieties were weighted equally in our analysis as we assumed that all the species had equal conservation values and that they should all be included in the prioritization solution. The warp factor was set equal to 200 [58,59]. To emphasize areas with higher model certainty, we established the default Zonation criterion (=1) as the uncertainty parameter [60–63]. We established all the other settings as described by Moilanen et al. [60] and Faleiro et al. [57]. The objective of this study was to conserve 30% of the region that we selected in northeastern China in accordance with Target Four of the Global Strategy for Plant Conservation (GSPC; <http://www.cbd.int/gspc/> (accessed on 15 December 2021); [64]). We used the entire land area of China as the ecological region of this research. We selected 30% of this ecological region, namely, the provided conservation proportion of distributions for species with high priority (Zonation conservation values  $\geq 0.7$ ), as PCAs for *Picea* species. Lastly, we used ArcGIS 10.4 (ESRI, Redlands, CA, USA) to compute the area and distribution of the PCAs. Habitat suitability results were expressed in probability, ranging from 0–1 [65]. Using the “Reclassify” tool of

ArcMap 10.3, the obtained probability results were divided into two levels, of which 0–0.7 was inappropriate and 0.7–1 was appropriate and high potential [66,67].

#### 2.4. Gap Analysis

According to the international biodiversity conservation roadmap, 30% of the territory should be protected by 2030 [68]. Honeck et al. (2020) [69] also showed that when the priority area is 30% (70–100%), it is the best high priority and zonation's outputs. Based on these, we retained 30% of the PCAs of *Picea* species in China under predicted climate conditions. Therefore, we regarded the potential distribution area of *Picea* species as the ecological region using MaxEnt to make full use of the land and adhere to the sustainable development strategy of China. Moreover, the threshold value of PCAs was extracted as the standard of conservation for each population and not vulnerable to the simulated predicted climate change. The terrestrial ecological region had to be considered in relation to the different national conditions. In this way, we were able to evaluate the efficacy of the existing national nature reserves and take appropriate measures to plan the construction of new conservation areas. We then analyzed the important existing national nature reserves for *Picea* species through computation of the PCAs.

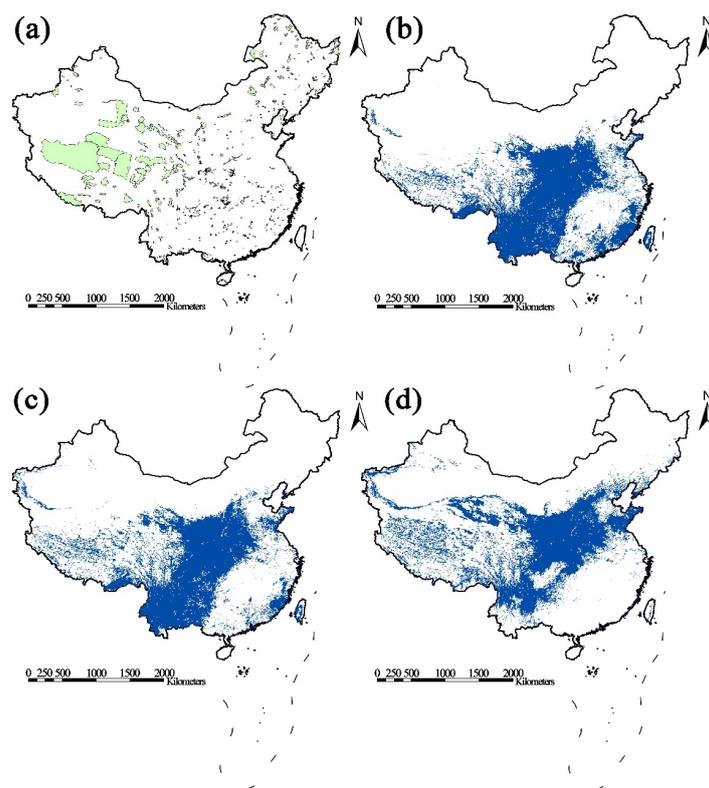
Considering that the target *Picea* species included two species and three varieties, niche overlapping could occur. The potential distribution area maps of five *Picea* species were used for spatial decision analysis and the potential distribution probability of these five *Picea* species under different climate models. We selected nature reserves with high distribution probability (probability > 0.7) [67] under current and predicted climates to analyze whether there was niche overlapping.

### 3. Results

#### 3.1. Changes in the Species Distribution of *Picea* Species

The AUC values predicted by MaxEnt based on several potential *Picea* species distribution variables were greater than 0.9, indicating that the MaxEnt model had good prediction results for the potential distribution area of the *Picea* species. The SDM and the results of the spatial analysis (Figure 1) showed that, as compared to the current distribution map (b), the species distribution area of the *Picea* species in China would change under the two predicted climate models ssp2-4.5 (c) and ssp5-8.5 (d). A comparison of the current (b) and predicted climate models indicated that there was little change in the distribution area of the *Picea* species under the ssp2-4.5 (c) scenario. The overall terrain of China is characterized by a stepped distribution of high in the West and low in the East [70]. When combined with the PCA distribution area map of the *Picea* species under the current climate (Figure 1b) and ssp5-8.5 predicted climate (Figure 1d), the PCA of the *Picea* species showed a norward trend, while the distribution area at high latitude and in western areas was increasing. The area of distribution of the *Picea* species showed a trend of moving to high latitude and altitude under the predicted ssp5-8.5 (d) climate model (Figure 1).

In the future scenarios ssp2-4.5, the distribution areas of *Picea* species that correspond to Qiangtang, Sanjiangyuan and the Qaidam Haloxylon Forest, Hoh Xil, and Qilian Mountain Nature Reserves in Gansu Province showed a tendency of increasing; whereas The Xishuangbanna and Dongzhai Nature Reserves showed an opposite trend (Table 1). Under the future ssp5-8.5 scenario, the reserves with a significant increase in the area of the *Picea* species included Qiangtang; Sanjiangyuan; Lop Nur Wild Camel; Hoh Xil; Altun Mountain; Qilian Mountain in Gansu Province; Qaidam Haloxylon ammodendron Forest and Annan Dam Wild Camel; Xishuangbanna Nature Reserve, a rare and unique fish nature reserve in the upper reaches of the Yangtze River; Yarlung Zangbo Grand Canyon; Dawei Mountain in Yunnan; Wuyi Mountain in Fujian; Huanglian Mountain; Nanling; Gaoligong Mountain; Nangunhe River; Leigong Mountain, and Huping Mountain (Table 1) (See Table S2 for the complete table).



**Figure 1.** (a) Distribution map of China's nature reserves. (b) Current distribution map of the *Picea* species. (c) The area of distribution of the *Picea* species in the climate priority conservation area under the predicted ssp2-4.5 scenario mode. (d) The area of distribution of the *Picea* species in the climate priority conserved areas of the *Picea* species under the predicted ssp5-8.5 scenario mode.

**Table 1.** Under the emission scenarios of ssp2-4.5 and ssp5-8.5, the distribution area of the studied *Picea* species PCAs in the national nature reserves.

Nature Reserves	Current	ssp2-4.5	ssp5-8.5
White Horse Snow Mountain	29	29	29
Wuyishan, Fujian	7	4	0
Annan dam Wild Camel	0	0	39
Baishuijiang	27	27	27
Gaoligong Mountain	50	50	44
Nanling	6	4	0
Lei Gongshan	7	7	2
Dong Zhai	4	0	0
Huping mountain	9	9	4
Hoh Xil	3	26	74
Qinghai Lake	26	28	28
Sanjiangyuan	336	489	508
Rare and endemic fish in the upper reaches of the Yangtze River	16	15	8
Qiangtang	73	347	1460
Selinco	142	142	142
Yarlung Zangbo Grand Canyon	77	77	69
Mount Qomolangma	65	65	65
Altun Mountain	0	4	63
Lop Nur Wild Camel	0	0	118
Huanglianshan	7	6	0
Nangunhe	6	6	0
Xishuangbanna	12	0	0
Changsha Gongma	7	17	22
Taohe River	22	22	22
Qaidam Haloxylon ammodendron Forest	2	33	54
The First Song of the Yellow River	21	21	21
Qilian Mountain, Gansu	57	80	112
Dawei Mountain, Yunnan	8	8	0

In the table, the nature reserves with more distribution of the *Picea* species or obvious changes under the influence of predicted climate conditions are selected for display. In the current climate and under the ssp2-4.5 and ssp5-8.5 emission scenario, the grid cells of five *Picea* species and varieties in national nature reserves were predicted. The numbers in the table indicate the area size.

### 3.2. Ability of the National Nature Reserves to Conserve *Picea* Species

Based on the regional analytical results of our spatial analysis, the total number of distribution grid cells in the nature reserves was 1748. Under the ssp2-4.5 emission scenario, there were 2221 grid cells in China's nature reserve, whereas the amount increased to 3648 under the spp5-8.5 scenario (Table 1). The results showed that the conservation capacity of *Picea* species in the National Nature Reserve under ssp5-8.5 was higher than the one obtained under a low emission scenario. In the low-emission scenario, climate change had a high positive impact on the *Picea* species in the Qiangtang, Sanjiangyuan, Qaidam Haloxylon Forest, Hoh Xil, and Qilian Mountain Nature Reserves (Table 1). In the high-emission scenario, climate change had a high positive impact on the Qiangtang, Sanjiangyuan, Lop Nur Wild Camel, Hoh Xil, Arkin Mountain, Qilian Mountain in Gansu Province, Qaidam Haloxylon Forest, and Annan Dam Wild Camel Nature Reserves (Table 1).

### 3.3. Conservation Gap

The predicted environmental conditions appeared to increase the distribution area of the *Picea* species outside some of the current national reserves. Based on the results of regional statistical analysis, we obtained the number of the studied species distributed outside China's land nature reserves under the current climate conditions and in two emission scenarios in the future (Figure 1). The total number of grid cells in the PCAs of the *Picea* species was 32,507. A total of 30,724 grid cells of the *Picea* species, and a total of 30,724 grid cells of the *Picea* species were located outside the nature reserves under the current climate conditions (Figure 1b). In the predicted low-emission scenario, 30,252 grid cells were distributed outside China's nature reserves (Figure 1c). In the predicted high-emission scenario, 28,846 *Picea* species grid cells were distributed across China (Figure 1d). Whether high or low emissions, most *Picea* species were distributed outside the nature reserve under the predicted climate conditions (Figure 1).

The sum of grid cells in and outside the nature reserve was not equal to the total number of grid cells. The error was due to a small number of nature reserves not being distributed entirely in China or the *Picea* species being distributed at the boundary of the nature reserve.

The results of the spatial decision analysis showed that niche overlapping occurred between *P. brachytyla* and *P. brachytyla* var. *comparata* in Gongga Mountain and Xiaojin Siguniang mountain. *P. likiangensis*, *P. likiangensis* var. *rubescens*, and *P. likiangensis* var. *linzhiensis* had niche overlapping in Dupangling, Yongzhou, upstream of Yalu River, and Yangmingshan. *P. likiangensis* and *P. likiangensis* var. *rubescens* had niche overlapping in Ordos relic gull (Table 2).

**Table 2.** Niche overlap analysis of five *Picea* species.

<i>Picea</i> Species	Nature Reserve Code			
Sp1	276	287	-	-
Sp2	276	287	-	-
Sp3	182	200	350	228
Sp4	182	200	350	228
Sp5	182	200	350	-

The codes of nature reserves with high probability of potential distribution of five *Picea* species under current and predicted climate. Sp1: *P. brachytyla*; Sp2: *P. brachytyla* var. *comparata*; Sp3: *P. likiangensis*; Sp4: *P. likiangensis* var. *rubescens*; Sp5: *P. likiangensis* var. *linzhiensis*. Nature Reserve Code 182: Dupangling, Yongzhou; Nature Reserve Code 200: Upstream of Yalu River; Nature Reserve Code 228: Ordos relic gull; Nature Reserve Code 276: Gongga Mountain; Nature Reserve Code 287: Xiaojin Siguniang mountain; Nature Reserve Code 350: Yangmingshan.

## 4. Discussion

### 4.1. Distribution of the *Picea* Species

The results of the spatial analysis showed that the predicted climate would have a significant impact on the distribution area of the *Picea* species. This could be due to the change in temperature and precipitation caused by climate changes, which affect the

habitat of the *Picea* species [71]. In particular, the change in the area of distribution in the nature reserves under the predicted ssp2-4.5 scenario increased the *Picea* species. The nature reserves with an obvious trend were concentrated in the high-altitude Qinghai Tibet Plateau in northwest China. This increase was significantly higher when the ss5-8.5 scenario was assessed. Changes in extreme temperature and precipitation caused by human activities would lead to a reduction in seasonal and perennial ice and snow ranges and an increase in sea levels [72]. Drought caused by warming has significantly affected forest dynamics in most regions of the northern hemisphere [73]. Factors such as temperature and precipitation have affected the range of distribution of the *Picea* species [74]. *Picea* species have been resistant to shade and cold and often grow in higher altitude areas [75]. In this study, a lower impact on the distribution area of *Picea* species is predicted under a low-emission scenario in comparison with a high-emission scenario. These findings could be explained by the differences in the expected changes in temperature and precipitation between both scenarios, being lower in ssp2-4.5. In the high-emission scenario, the warming trend was more apparent [76], which led to the movement and expansion of the area of distribution from low latitudes and altitudes to high latitudes and altitudes. This trend was similar to the findings reported by previous research, which showed that the niche of this genus had a northward trend [77,78].

#### 4.2. Conservation Ability of the National Nature Reserves

We used the Zonation conservation planning software (<http://cbig.it.helsinki.fi/software/> (accessed on 1 December 2021)) to develop conservation plans for the *Picea* species. Zonation is typically used as a spatial conservation prioritization framework for the large-scale conservation planning of multiple biodiversity features (e.g., species), but we adopted the use of the Zonation algorithm to establish the conservation areas for *Picea* species across large space–time scales. The highest priorities for conservation, namely conserved areas of genetic diversity, were confirmed by identifying the top-ranking cells after computation.

Conserved areas, such as nature reserves, have been effective in the prevention of habitat destruction and the conservation of ecosystems [79]. This study showed that some priority conservation areas of the *Picea* species coincided with the areas of distribution of the nature reserves, which showed that national nature reserves had sufficient capacity to conserve the *Picea* species, indicating the necessity of establishing new nature reserves. In the low-emission scenario, the PCA distribution area of the current *Picea* species increased, and the event was more significant in the high-emission scenario. It indicated that in the predicted high-emission scenario, the conservation capacity of national nature reserves for *Picea* species was better than that in the low-emission scenario. Studies have shown that nature reserves promote the increase in forest coverage and areas most suitable for a species [80]. The nature reserves had sufficient capacity to conserve water, reduce grazing intensity and human disturbance factors, and conserve grassland vegetation in fragile habitats [81]. The forests in the nature reserve had significant ecological benefits and were highly efficient at maintaining the ecological security of their immediate and surrounding areas [82].

#### 4.3. Conservation Gap Analysis

More efforts will be necessary to expand the scope of conservation based on increasing nature reserve areas. A significant number of the *Picea* species are located outside the reserves, and these are under even more threats. Xu et al. (2019) [48] proposed the establishment of a national park administration to separate management and supervision and establish spatial planning for the diversity of national representative species, ecosystems, and natural landscapes. This strategy could promote a balance between conservation planning and management, similar to the objective of this study. More nature reserves should be established in the areas that are suitable for the *Picea* species by constructing a reserve network to conserve the biodiversity of the *Picea* species. Local species and ecosystems

should be conserved, and the focus should not only encompass areas with the highest biodiversity [83]. Environmental degradation and difficult natural regeneration should be avoided since excessive deforestation leads to sporadic growth. The spatial decision support system effectively and directly analyzed the characteristics of the *Picea* species distribution in China under predicted climate conditions, assisted in finding the relationship between *Picea* species priority conservation areas and nature reserves, and provided a reliable reference for the predicted system conservation planning for this valuable genus.

In some nature reserves under current and predicted scenarios (Table 2), niche overlapping occurred among the *Picea* species and their variants. This was attributed to the similar niche between the variant and the original, so niche overlapping could occur in environments with limited resources [84]. In the management of nature reserves, we should consider the different degrees of niche overlapping in different nature reserves.

Our research had certain limitations. For example, regarding the spatial decision support system, our research had insufficient data and could only conduct general research. Therefore, we need to gather more data for future research [85]. In addition, the difference between the data and the models involved in the various processes to be integrated also affected the spatial decision system. A decentralized, bottom-up forest planning approach that consistently allows the cells to coevolve until the plans of all periods within the planning horizon are achieved [86] would resolve this issue. Nowakowska et al. (2020a) [87] and Berezovska et al. (2021) [88] studied the pathogens transmitted in soil and found that soil pathogens had a negative impact on the growth of trees. Nowakowska et al. (2020b) [89] researched Norwegian spruce trees using bark beetles (*IPS typographus* L.) in Polish forest areas to show that insects could also threaten the growth of spruce trees. We only considered the environmental impacts at a macro level, not the micro level. Even with these limitations, however, our study provided significant results.

## 5. Conclusions

This study examined five *Picea* species varieties to comprehensively predict the distribution of the *Picea* species under the influence of predicted climate conditions in China. The research also showed the conservation capacity of nature reserves for the *Picea* species. This research contributed to previous literature on the *Picea* species and the conservation capacity of nature reserves under climate change conditions. The *Picea* species has been a focus of research in botany. This research simulated the potential geographical distribution areas of the *Picea* species based on a spatial decision support system, which indicated scientific zoning for the suitable growth and conserved areas of the *Picea* species in China, and provided a scientific basis for the biodiversity conservation and management of the *Picea* species.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su14127406/s1>, Table S1: Five *Picea* species data from field survey and Chinese Virtual Herbarium (CVH; [www.cvh.org.cn](http://www.cvh.org.cn)); Table S2: The predicted distribution area of *Picea* species under the current climate and the future climate of the two emission scenarios.

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data were obtained from WorldClim (<https://worldclim.org/> (accessed on 1 December 2021)). Data of China's national nature reserves were obtained from the Resource and Environmental Science and Data Center (<https://www.resdc.cn/Default.aspx> (accessed on 5 December 2021)).

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