Spatiotemporal Heterogeneity of Ecological Policy Compromises Human Well-Being and Giant Panda Habitat Conservation in Giant Panda National Park

Dan Zhu 1,2,3 and Degang Yang 1,*

1 Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China; zhudan@cib.ac.cn or goff@ms.xjb.ac.cn
2 Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu 610041, China
3 University of Chinese Academy of Sciences, No. 19A Yuquan Road, Beijing 100049, China

Abstract: Identifying how policy, socioeconomic factors, and environmental factors influence changes in human well-being (HWB) and conservation efficiency is important for ecological management and sustainable development, especially in the Giant Panda National Park (GPNP). In this study, we systematically analyzed the differences in the conservation status of the giant panda habitat and changes in HWB over 15 years in the GPNP, which includes six mountain sites, Minshan (MS), Qionglai (QLS), Xiaoxiangling (XXL), Liangshan (LS), Qinling (QL), and Daxiangling (DXL). Redundancy analyses were used to determine the factors contributing (policy, socioeconomic factors, and environmental factors) to HWB and giant panda habitat conservation (HC). In addition, using a structural equation model (SEM), we investigated the relationship between the aforementioned three factors and their direct and indirect effects on HWB and HC. The results indicated that there was spatiotemporal heterogeneity of HWB and HC in our study area. There was an increasing number of plant species as well as an increased number of giant panda in GPNP. Generally, HWB in 2015 showed an increasing trend compared with that in 2000. Socioeconomic factors (23.6%) have the biggest influence on HWB and HC, followed by policy (23.2%) and environmental factors (19.4%). Conservation policy had a significantly positive influence on HWB (0.52), while it negatively influenced HC (−0.15). Socioeconomic factors significantly negatively influenced HWB (−0.38). The formulation and implementation of policies to promote economic development will contribute to the protection of giant pandas and their habitat. Our results provide insight on the conservation status of the giant panda habitat, HWB, and factors influencing them in different mountain sites in the GPNP, as well as having implications for the future management of the GPNP.

Keywords: human well-being; Giant Panda National Park; conservation; management; conflict

1. Introduction

According to the Millennium Ecosystem Assessment, human well-being is linked to ecological conditions; therefore, effective environmental management should provide a wide range of benefits for humans, which will result in positive synergies between environmental conditions and human well-being [1]. However, based on numerous protection and management practices, studies have shown that the goal of protection is often in conflict with the needs of local residents for social and economic development, which limits the effectiveness of the protected area [2–4]. This is particularly common in China’s protected areas, which are located in remote, poor areas; therefore, there can be intense conflict between ecological conservation and local socioeconomic development. If an effective solution cannot be proposed, the conflict may intensify and may have a negative impact on human well-being.
Ecosystem services (ES) refer to the contributions, directly or indirectly, to human well-being that originate from an ecosystem [5]. In other words, there is a strong connection between ES and human well-being [6]. Recently, an increasing number of studies concerning the relationship between ecosystem services and human well-being have been published, which not only promote the development of this field but also increase attention to this field [6–8]. Conservation policies have an impact on ES, which in turn, can have an effect on human well-being.

Given the enormous conservation value of giant panda habitat and the urgent threats to it, the Chinese government has implemented several heavily funded conservation policies: the National Giant Panda and Its Habitat Conservation Project (NGPP), the National Wildlife Conservation and Nature Reserve Construction Project (NCNCP), the Grain for Green Project (GTGP), and the Natural Forest Conservation Project (NFCP) [9–13]. The conservation of giant pandas and their habitat positively benefited from these large-scale conservation policies [14–16]. Moreover, the outcome of the increased wild giant panda population and the extension of the protected habitat provided the basis for the International Union for Conservation of Nature (IUCN) to downgrade the extinction risk for the giant panda from endangered to vulnerable [17]. However, factors including human disturbance, climate change, and habitat fragmentation still threaten the long-term survival of the giant panda [14,15,17–19]. Therefore, in order to improve the connectivity between isolated giant panda populations and habitat, and ultimately achieve a sustainable population in the wild, the Chinese government has finalized a plan to establish a Giant Panda National Park (GPNP). Specifically, in 2020, 18,101 km$^2$ of known giant panda habitat and 1864 of known wild giant pandas are supposed to be encompassed and protected under one authority in order to improve the effectiveness and reduce inconsistencies in management [20,21].

However, the question of whether and how to incorporate spatial heterogeneity into the management of the GPNP is, therefore, pressing. Since townships in the national park differ in their biophysical attributes and socioeconomic characteristics, similar yet well-intentioned conservation efforts could lead to disparate outcomes [22]. Empirically assessing the conservation status of the giant panda habitat and human well-being in the GPNP can provide basic knowledge needed to maintain and enhance suitable panda habitat and the implementation of conservation policies to better achieve the desired protection objectives.

2. Materials and Methods

2.1. Study Area

The study area covers six mountain sites where giant pandas (*Ailuropoda melanoleuca*) are currently distributed, including Minshan (MS), Qionglai (QLS), Xiaoxiangling (XXL), Liangshan (LS), Qinling (QL), and Daxiangling (DXL) (Figure 1). Results from the Fourth National Survey on Giant Pandas found that a total of 1864 wild giant pandas live in these mountain sites [20]. Moreover, these regions are considered a global biodiversity hotspot, containing many priority areas for conservation in China [23].

2.2. Data Collection

From July to August 2016, residents in and around the GPNP were requested to take part in a questionnaire. Respondents were asked to provide information on human well-being at two time points, 2000 and 2015. Based on the impact of ecosystem services on human well-being, the Millennium Ecosystem Assessment proposed a human well-being assessment framework, describing human well-being from five aspects: security, basic material needs, health, good social relations, and freedom of choice and action [1]. The questionnaires of human well-being used in this study were designed to fit the five aspects mentioned above. In total, 150 questionnaires were collected for each mountain site by conducting one-on-one interviews with randomly selected individuals. Among the obtained questionnaires, 799 questionnaires (136, 144, 128, 134, 139, and 118 questionnaires were...
obtained in MS, QLS, XXL, LS, QL, and DXL, respectively) were included in downstream analyses. Moreover, combined with semi-structured interviews, we conducted in-depth research to obtain a more accurate picture of human well-being in different locations.

**Figure 1.** Distribution of the plots in the giant panda habitat (Sichuan Forestry Department provided habitat and potential habitat boundaries). There are a total of 165 revisited plots in six mountain sites.
Regarding the investigation of the conservation status of the giant panda habitat, we used the changes in the giant panda population, habitat area, and plant diversity in panda habitat to represent the overall conservation status. Data from the Third and the Fourth National Survey on Giant Pandas were used to analyze changes in the giant panda population and habitat area [20]. Then, for the changes in the plant diversity in the panda habitat, a total of 165 plots (20 m × 30 m) were randomly selected from a number of samples for long-term monitoring by the research team \( n = 500 \). These 165 plots were all situated in typical panda habitat, specifically, in temperate coniferous or broad-leaved mixed forests, particularly where bamboo was present (e.g., *Bashania fangiana*, *Fargesia nitida*). The first survey of these sampling plots was conducted by the Chengdu Institute of Biology, Chinese Academy of Sciences, in 2001. We re-surveyed these plots using the same methods in 2015 (Figure 1). Within each plot, we re-surveyed and recorded all tree species, the number of individuals of each species (abundance), and horizontal area of canopy coverage (%). Moreover, vegetation surveys were conducted between July and September in each survey year (the peak period of plant growth). Two earthquakes in 2008 and 2013 had negligible effects on the 165 plots, and no extreme climatic events, pest outbreaks, or fires occurred during the study period from 2000 to 2015 [19].

2.3. Statistical Analysis

2.3.1. Evaluation of the Conservation Status of the Giant Panda Habitat

The changes in the number of giant panda individuals and habitat area in six focused mountain sites are important indicators to evaluate the conservation status of the giant panda habitat. The data were obtained from the official book compiled by the State Forestry Administration (State Forestry Administration 2006) and a publication from Tang et al., 2015 [24].

Another indicator used to evaluate the conservation status of the giant panda habitat was changes in plant community composition in the habitat of giant pandas. The evaluation in this study was mainly focused on tree species diversity because tree species data were the most complete in 2000, allowing the data to be used in a comparative analysis. Here, we classified 165 plots based on their location in the six mountain sites to investigate whether or not the beta diversity of tree species would change in different mountain sites.

To compare compositional/diversity change among mountain sites, we first calculated the annual rate of change rate tree richness, species abundance, and beta diversity indicator (the net change rate over time within local areas) as \( \frac{X_{\text{final}} - X_{\text{initial}}}{t} \), where \( t \) is the census interval (in years) and \( X \) is the value of the response variable of interest at the final and initial survey. For each variable, we performed an analysis of variance (ANOVA) and least significance difference (LSD) test using the RSTAT2D package v1.0 in R v3.4.3 [25] to determine significant differences in shifts in the plant community between mountain sites.

2.3.2. Assessment of Human Well-Being

Subjective well-being was measured on a 10-point scale by asking “Generally, how do you rate the quality of life in your family?” and “Generally, how happy do you think your family is?”. Then respondents were asked to rate their satisfaction on a scale of 1 to 10, with 1 being very dissatisfied and 10 very satisfied. Scores of the corresponding questions collected in the same mountain site were averaged. Furthermore, based on the human well-being evaluation framework from the perspective of sustainable development [1], five aspects describing human well-being: security, basic material needs, health, good social relations, and freedom of choice and action were measured using the same methods. The respondents were asked to measure the satisfaction with their own life from questions related to the aforementioned topics on a scale of 1 to 5, with 1 being very dissatisfied and 5 very satisfied. Then, the scores of corresponding questions in each of the topics were added and the average value was obtained.

In addition, a redundancy analysis (RDA) was applied to interpret the impact of common factor of policy, socioeconomic, and environment variables on human well-being.
and the conservation status of the giant panda habitat. In the RDA, factors including protected area (km²), GTGP area (m²/person), GTGP subsidy (yuan/person), number of migrant workers, gross domestic product (GDP), human influence index (HII), population, elevation, precipitation (mm), and average temperature (°C) were investigated to determine their influences on the changes in human well-being in different mountain sites. All variables were Ln(x + 1)-transformed (normalized) before inclusion in the RDA. Factors considered were also divided into three categories: policy factors, socioeconomic factors, and environmental factors. In this study, RDA was conducted using RStudio.

2.3.3. Factors Contributing to the Changes in Human Well-Being and the Conservation Status of the Giant Panda Habitat

A structural equation model (SEM) was employed to investigate the direct and indirect influence of policy factors, socioeconomic factors, and environmental factors on the changes in human well-being and the conservation status of the giant panda habitat [26]. We began with an initial SEM model based on predictions and experimental results from the current study, assuming that human well-being and the conservation status of the giant panda habitat could be altered by ecological policy, socioeconomic factors, and environmental factors. Both tree richness and giant panda population were significantly associated with ecological policy and environmental factors, thus were used as indicators of the conservation status of the giant panda habitat. Additionally, the GTGP subsidy and the area of GTGP in each mountain site were used as indicators of conservation policies. Precipitation and average temperature were used to represent the environment. Net income and human influence index were used as indicators of socioeconomic factors. We removed the influence factor and path (non-significant paths) based on the performance of the SEM and the p-value of the path. Single-headed arrows represent causal relationships. Numbers on arrows correspond to standardized path strength. The SEM was evaluated using two criteria: a chi-square (χ²) test (p > 0.05 is deemed a satisfactory fit) and the standardized root mean square residual (SRMR < 0.05 is deemed a satisfactory fit; Grace, 2006). We used the lavaan package v0.6-8 in R v3.4.3 [25] to build the SEM.

3. Results

3.1. The Conservation Status of the Giant Panda Habitat in Different Study Periods

The results of the Third and the Fourth National Survey on Giant Pandas indicated that the number of giant pandas generally increased in the wild panda population in MS, QLS, LS, QL, and DXL, while there was a declining trend in the wild panda population in XXL (Table 1). The area of the giant panda habitat increased in all the six studied mountain sites (Table 1).

Table 1. Number of giant pandas and area of habitat in the six mountain sites and the changes in the panda population and habitat area in different mountain sites. MS, Minshan Mountain; QLS, Qionglai Mountain; XXL, Xiaoxianglin Mountain; LS, Liangshan Mountain; QL, Qinling; and DXL, Daxianglin Mountain.

|                  | The 3rd National Survey on Giant Pandas | The 4th National Survey on Giant Pandas |
|------------------|----------------------------------------|----------------------------------------|
|                  | Individual | Habitat Area (km²) | Individual | Habitat Area (km²) |
| MS               | 708        | 9603               | 797        | 9713               |
| QLS              | 437        | 6101               | 528        | 6888               |
| XXL              | 32         | 802                | 30         | 1194               |
| LS               | 115        | 2204               | 124        | 3024               |
| QL               | 29         | 810                | 38         | 1229               |
| DXL              | 275        | 3529               | 347        | 3719               |

A total of 182 tree species were recorded in the initial year throughout all 165 plots, which increased slightly to 194 species in 2017. In general, there was an increase in
tree species in the plots monitored in each mountain site, except in LS, which showed a slight decrease in the number of tree species (Figure 2a). However, the differences between mountain sites were not significant, except for LS. Tree abundance increased significantly over time at MS, QLS, XXL, QL, and DXL, while it decreased slightly in LS. The change in abundance was significantly higher in MS, QLS, XXL, QL, and DXL than in LS, which exceeded the rate of change in species richness over time. However, beta diversity underwent a significantly higher rate of change in LS than in the other mountains (Figure 2b) ($F_{3,103} = 4.60, p = 0.0033$) and beta diversity was significantly lower in QLS versus the other five mountain sites.

![Figure 2a: Tree richness](image)

![Figure 2b: Tree beta diversity](image)

**Figure 2.** Tree richness (a) and tree beta diversity (b) in six mountain sites in 2000 and 2017. MS, Minshan Mountain; QLS, Qionglai Mountain; XXL, Xiaoxianglin Mountain; LS, Liangshan Mountain; DXL, Daxianglin Mountain.

### 3.2. Evaluation and Analysis of Human Well-Being

In 2000, the score of subjective well-being in XXL was higher than that in the other five mountain sites. Specifically, the score of subjective well-being in XXL was $6.53 \pm 0.23$, DXL was $6.17 \pm 0.26$, $6.44 \pm 0.32$ in MS, $6.38 \pm 0.41$ in QL, $6.15 \pm 0.34$ in QLS, and $5.91 \pm 0.43$ in LS (Table 2). There were significant differences between subject well-being in LS and the other five mountain sites ($p < 0.05$), whereas there was no significant difference among human well-being in the other mountain sites, except for LS (Table 2). In 2015, the score of subjective well-being in Minshan Mountain was higher than that in the other five mountain sites. There was no significant difference between human well-being in the six mountain
sustainability sites in 2015 (Table 2). When comparing the human well-being in the same mountain site from different time points, the results showed that there was a significant difference among the mountain sites \( (p < 0.05) \), except for the human well-being in QLS and XXL. Generally, the subjective well-being of residents from the six studied mountain sites improved.

Table 2. Scores (mean ± standard deviation (SD)) of corresponding questions in five topics related to human well-being (security, basic material needs, health, good social relations, and freedom of choice and action). MS, Minshan Mountain; QLS, Qionglai Mountain; XXL, Xiaoxianglin Mountain; LS, Liangshan Mountain; and D XL, Daxianglin Mountain.

| Phase | Aspect          | Value         | MS ± SD | QLS ± SD | XXL ± SD | LS ± SD | QL ± SD | DXL ± SD |
|-------|-----------------|---------------|---------|----------|----------|---------|---------|---------|
| 2000  | Basic materials | 3.33 ± 0.38  Aa | 3.48 ± 0.35  Ab | 3.16 ± 0.38  Aa | 3.04 ± 0.39  Ab | 3.17 ± 0.32  Ab | 3.12 ± 0.35  Ab |
|       | Security        | 3.47 ± 0.33  Aa | 3.35 ± 0.32  Ab | 3.58 ± 0.34  Aa | 3.21 ± 0.22  Ab | 3.48 ± 0.29  Ab | 3.19 ± 0.27  Ab |
|       | Health          | 3.7 ± 0.35  Aa | 3.37 ± 0.42  Ab | 3.71 ± 0.38  Aa | 3.42 ± 0.32  Ab | 3.39 ± 0.28  Ab | 3.51 ± 0.23  Ab |
|       | Relations       | 3.87 ± 0.21  Ab | 3.71 ± 0.31  Ab | 4.12 ± 0.27  Ab | 4.25 ± 0.26  Ab | 4.16 ± 0.32  Ab | 4.12 ± 0.29  Ab |
|       | Freedom         | 3.72 ± 0.33  Ab | 3.92 ± 0.23  Ab | 3.62 ± 0.33  Ab | 3.22 ± 0.37  Ab | 3.23 ± 0.21  Ab | 3.24 ± 0.23  Ab |
|       | Subject well-being | 6.44 ± 0.32  Ab | 6.38 ± 0.41  Ab | 6.53 ± 0.23  Ab | 5.91 ± 0.43  Ab | 6.15 ± 0.34  Ab | 6.17 ± 0.26  Ab |

The respondents were asked to rate their own life using questions related to the above-mentioned topics on a scale of 1 to 5, with 1 being very dissatisfied and 5 very satisfied. Different capital letters for a given variable indicate a significant difference in the same mountain site \( (p < 0.05) \), while the lowercase letters indicate significant differences \( (p < 0.05) \) at a different time point based on one-way analysis of variance (ANOVA), followed by a Tukey test. Different lowercase letters for a given variable indicate significant differences \( (p < 0.05) \) between different mountain sites based on a t-test.

When describing human well-being based on basic material needs, health, good social relations, and freedom of choice and action, results from the data analysis indicated that in the year 2000, residents of QLS felt more satisfied with basic materials and freedom of choice and action compared to other mountain sites, while residents of LS had the lowest satisfaction. Residents of XXL felt more satisfied with security and health, while residents of LS felt more satisfied with social relations (Table 2). In contrast, residents of D XL worried most about their security, whereas residents of QL worried most about their health (Table 2). Results from the data analysis in 2015 showed that residents of QLS still felt more satisfied with basic materials and freedom of choice and action compared to other mountain sites, while residents of LS still think they have better relationships with their neighbors (Table 2).

When comparing every aspect of human well-being in each mountain site from different time points, the results showed that satisfaction with basic material needs increased significantly, while there were no significant differences in the other four sites (Table 2). When comparing every aspect of each mountain site with different mountain sites at the same time point, in 2000 and 2015, relationships were the highest in LS and the lowest in WLS, and there was a significant difference \( (p < 0.05) \).

3.3. Factors Contributing to the Changes in Human Well-Being and Conservation Status of Panda Habitat

The RDA results showed the first and second axes explained 33.82% and 16.73% of the total changes in human well-being and the conservation status of the giant panda habitat, respectively. The results suggested that the number of migrant workers, GDP, area of GTGP, subsidy of GTGP, and elevation have positive effects on human well-being. Specifically, the higher the value of these factors, the higher the human well-being, whereas population and temperature have negative effects on the human well-being; for these factors the higher the value, the lower the human well-being (Figure 3a).
Figure 3. Ordinate plot from the redundancy analysis (RDA) of changes in human well-being and the conservation status of the giant panda habitat and their relationships with policy factors, socioeconomic factors, and environmental factors (a) and variance partitioning revealed the contribution of the variables (policy factors, socioeconomic factors, and environmental factors, and the residual variance) to the changes in human well-being and the conservation status of the giant panda habitat (b). GTGP, Grain-to-Green Program; HWB, human well-being; T, temperature; HII, human influence index; policy factors, X1; socioeconomic factors, X2; environmental factors, X3.

Regarding the panda population, a larger protected area can benefit the growth of the panda population, while temperature, HII, and precipitation are negatively correlated with the size of the giant panda population (Figure 3a). Furthermore, protected area was also positively correlated with the tree richness and tree beta diversity. In addition, the more migrant workers, the higher the GDP, tree richness, and tree beta diversity (Figure 3a).

When considering the three categories: policy factors, socioeconomic factors, and environmental factors, our results showed that socioeconomic factors (X2, 23.6%) had the greatest influence on the changes in human well-being and the conservation status of the giant panda habitat, followed by the policy factors (X1, 23.2%); environmental factors (X3, 19.4%) had little effect on the changes (Figure 3b). Furthermore, when exploring how these three factors influence the changes in human well-being and the conservation status of the giant panda habitat, there were strong interactions between policy factors (X1) and environmental factors (X3) (0.127), whereas there were weak interactions between policy factors (X1) and socioeconomic factors (X2) (0.001) as well as socioeconomic factors (X2) and environmental factors (X3) (0.002) (Figure 3b).

3.4. The Paradox of Policy and Socioeconomic Factors on Human Well-Being and Conservation Status of Panda Habitat

The best SEM (Figure 4) explained subject well-being and the conservation status of the giant panda habitat at 59% and 79%, respectively (df = 45, p = 0.13 > 0.05; SRMR = 0.047 < 0.050). A satisfactory fit of the data suggested the SEM was valid for use determining how ecological policy, socioeconomic factors, and environmental factors affected human well-being and the conservation status of the giant panda habitat. According to this model, conservation polices had a significantly positive influence on human well-being (0.52) and socioeconomic factors had a significantly negative influence on human well-being (−0.38). The conservation status of the giant panda habitat had a slight influence on human well-being (0.02).
Figure 4. Structural equation model (SEM) depicting the effects of policy, socioeconomic, and environmental factors on the changes in human well-being and the conservation status of the giant panda habitat in Giant Panda National Park (GPNP; df = 45, \( p = 0.13 > 0.05 \); standardized root mean square residual (SRMR) = 0.047 < 0.050). *, significant direct effects \( (p < 0.05) \).

HWB, human well-being; HC, the conservation status of the giant panda habitat.

Conservation policies as a whole were negatively correlated with the conservation status of the giant panda habitat \((-0.15)\), environmental factors were significantly negatively correlated with the conservation status of the giant panda habitat \((-0.60)\), and socioeconomic factors were significantly positively correlated with the conservation status of the giant panda habitat \((0.58)\).

4. Discussion

Previous studies have primarily focused on the changes in human well-being over time, the changes in human well-being under the influence of natural, socioeconomic, and policy factors, or the relationship between factors such as ecosystem services, policy, and human well-being \([19,27]\); however, few studies have evaluated how much each factor affects human well-being. To our knowledge, no previously published study has explored the spatiotemporal heterogeneity on human well-being, the conservation status of the giant panda habitat in the GPNP, and factors contributing to them. Here we proposed an innovative framework that incorporates policy, socioeconomic, and environmental factors to determine changes in human well-being and habitat conservation status in different regions. We found that, despite the difference in human well-being and panda habitat conservation status in different mountain sites, there is a relatively consistent trend in the relationships between socioeconomic factors, human well-being, and the conservation status of panda habitat in the GPNP (Figure 3b). Additionally, according to further SEM analysis, socioeconomic factors were significantly negatively correlated with subject well-being and significantly positively correlated with the conservation status of the giant panda habitat (Figure 4).
4.1. Differences in the Habitat Conservation Status in Different Mountain Sites and Potential Drivers of These Differences

Except for the increasing trend in the panda population and the area of panda habitat, the results of comparing the differences of plant communities showed that, in general, there was also an increase in tree species in the plots monitored in each mountain site, except in LS, which showed a slight decrease, while as for tree community composition, this indicator of XXL was particularly different from the other five mountain sites (Figure 2). First, the plant communities have different structures depending on the location, which may influence the succession of the whole community, leading to differences in biodiversity and ecological functions [28]. Second, human interference (such as logging and grazing), climate change, and difference in time and area of implementation of the protection project (such as the Natural Forest Conservation Program and the GTGP) in different mountain sites are likely to be the most important factors [29].

The prevalence of human activities, such as logging and grazing, in the giant panda reserve likely impact the long-term survival of the giant panda as well as the plant community in the giant panda habitat. Major human disturbance activities in different mountain sites may vary [20,30], which may result in different impacts on the plant community. A previous study conducted in the Wolong Nature Reserve in QLS showed that livestock grazing impacted shrubs and herbs, while it had a negligible effect on trees [2]. However, when the time scale of the study is relatively long, such as more than 40 years, the results may be quite different. Climate change can have effects on forest development and plant biodiversity through various mechanisms and interactions [31]. Therefore, changes in the plant community in different mountain sites over the past 15 years may also be related to changes in climate in different mountain sites. In the future studies, taking the aforementioned factors into consideration will be helpful to further clarify the potential drivers of these changes.

4.2. Impact of Specific Factors on the Changes in the Conservation Status of Panda Habitat and Human Well-Being

Comparing the data from the Third and the Fourth National Survey on Giant Pandas, our findings suggested that the giant panda population and habitat area in the six studied mountain sites showed an increasing trend. An RDA was used to determine the correlation between each factor considered in this study and the change in panda population. The findings revealed that larger protected areas showed an increase in the panda population size; in China, there are 67 nature reserves specifically for giant panda conservation [2], increasing the number of protected areas provided the basis for the increase in the population of the giant panda [24]. Environmental factors, including temperature and precipitation, were negatively correlated with the giant panda population size, since most endangered species, like the giant panda, are specialists confined to restricted habitats, are less physiologically tolerant of environmental changes, and less able to migrate/disperse to adapt climate change and human disturbance [2,32–34]. Therefore, when HII was high or temperature and precipitation were not suitable for giant pandas, a negative impact was observed on the giant panda population size.

Generally, human well-being in 2015 was greater than that in 2000, indicating that the quality of life improved and life satisfaction increased, which is consistent with previous research that showed most aspects of human well-being improved [6,35]. However, in some specific cases, for example, the 2008 earthquake in Wenchuan negatively impacted the residents in the QLS site. A previous study found that the overall human well-being of residents decreased in 2009, just after the earthquake, compared with 2007, and has been recovering in 2014 [27].

In this study, we found out that the subsidy and area of the GTGP, number of migrant workers, and elevation were positively correlated with human well-being. The larger the GTGP area, the greater the GTGP subsidies, resulting in increased human well-being due to the increase in income from a GTGP subsidy. Regarding the strong correlation
between human well-being and elevation, our research was carried out in six mountain sites in two different years; therefore, the sample size may not be sufficient to clearly reveal the relationship between the two. Additionally, the overall elevation and subject well-being in XXL were relatively high, which may lead to the existing results. Few studies have specifically analyzed the relationship between well-being and elevation [6]; therefore, future research is needed to determine the correlation between human well-being and elevation.

4.3. Formulation and Implementation of Policies to Promote Economic Development Will Contribute to the Protection of Giant Pandas and Their Habitat

Forest ecosystems are critical to human well-being because forest biodiversity consolidates social welfare by preserving ecosystem multifunctionality and the provision of ecosystem goods and services [31]. The correlation between ecosystems and human well-being is positive [6], thus effective conservation of the giant panda habitat can benefit human well-being locally. However, in this study, our SEM results showed that there is little interaction between human well-being and the conservation status of the giant panda habitat, which could be because the conservation status of panda habitat in the GPNP was originally in good condition, therefore, a slight improvement in panda habitat would not have much impact on the well-being of local residents.

The results from the RDA showed that socioeconomic factors (X2, 23.6%) had the largest influence on the changes in human well-being and the conservation status of the giant panda habitat (Figure 3). Moreover, the SEM (Figure 4) revealed that socioeconomic factors significantly positively influenced the conservation status of the giant panda habitat (0.58), indicating that formulation and implementation of policies to promote economic development will contribute to the protection of giant pandas and their habitat. Surprisingly, socioeconomic factors significantly negatively influenced human well-being (−0.38), meaning that more a developed economy is not always associated with higher human well-being in GPNP. Previous studies suggested that income plays an important role in the structure of human well-being and its increase promotes the consumption of basic material demands and improves the level of human well-being in the context of education, health care, health, and freedom [6,8]. However, large numbers of tourists flocked to the GPNP in the past 15 years. This leads to increased pressure on the local environment, which leads to a decrease in human well-being. Moreover, agriculture is the main source of income for local residents, but in recent years, there has been a significant increase in incidents of wildlife damaging farmland, which has led to a decrease in human well-being (Figure 5).

Identifying the outcome of policy implementation is of great concern to policy makers, especially for policies that are implemented on a large scale and may have different impacts in different regions [26]. The implementation of conservation policies like the GTGP which is a conservation set-aside program designed to restore fragile ecosystems damaged by unsustainable farming and grazing [36,37] have enhanced the habitat of giant pandas; however, there is evidence that large-scale afforestation in vulnerable arid and semi-arid regions could increase the severity of water shortages, decrease vegetation cover in afforestation plots, and adversely affect the number of species present [37]. The results from the SEM showed that conservation policies as a whole were negatively correlated with the conservation status of the giant panda habitat (−0.15), which is consistent with the findings reported by Cao et al., 2009 [37].
5. Conclusions

In this study, we identified different conditions of human well-being and the conservation status of the giant panda habitat on a spatiotemporal scale and the direct and indirect effects of policy, socioeconomic, and environmental factors on the changes in human well-being and the conservation of the giant panda habitat. Our results suggested that formulation and implementation of policies to promote economic development will contribute to the protection of giant pandas and their habitat. Our results confirmed that investigating the impacts of spatiotemporal heterogeneity on human well-being and conservation of the giant panda habitat in the GPNP and factors contributing to the changes can provide valuable insights into the understanding of different responses of local residents to the conservation measures and subsidy policies from different regions. Furthermore, these findings provide basic knowledge for formulating and implementing more scientific and effective protection and management measures.

Author Contributions: All authors worked together to design this study. D.Z. and D.Y. contributed to initiating and conceiving the topic of this paper; D.Z. collected the data and did the analysis; D.Z. and D.Y. wrote the draft of this paper; all authors contributed substantially to modify and revise this paper. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China, grant numbers 31500589, and 41761144079.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: Project financed from the National Natural Science Foundation of China, grant numbers 31500589, and 41761144079.

Conflicts of Interest: The authors declare no conflict of interest.
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