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Impacts of the Wenchuan Earthquake on the Giant Panda Nature Reserves in China

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Abstract: The Wenchuan Earthquake that occurred in May of 2008 caused damages to large areas of Sichuan, Gansu, and Shaanxi provinces in China. Reports from local governments and related management agencies show that the giant panda nature reserves in the earthquake-hit areas were heavily damaged. Our estimates in this paper of the impacts of the earthquake on the giant panda in the earthquake-hit areas were made based on the interpretation of remote sensing images and information collected by field survey. A rapid assessment method was designed to estimate the damages of the earthquake on giant panda habitats. By using visual interpretation methods, we decoded the remote sensing images of the disaster area in the 49 giant panda nature reserves. Research results showed that the Wenchuan Earthquake and the succeeding secondary geological disasters caused great damages to the giant panda nature reserves and disturbed the normal life of the giant pandas there (e.g., landscape fragmentation increased significantly). Undoubtedly, the life of the giant pandas there was affected. However, although the earthquake caused certain impacts on the giant pandas, it did not really threat their survival. Even so, we still strongly advocate for protection of the giant pandas, and have prioritized a couple of measures to be taken to restore the giant panda nature reserves in the earthquake-hit areas.

Keywords: Wenchuan earthquake; Remote sensing; Giant panda; Giant panda nature reserve; Rapid assessment method

Introduction

At 14:28 (Beijing time), May 12, 2008, the Wenchuan Earthquake, measuring 8.0 on the Richter scale, struck Sichuan, Gansu, and Shaanxi provinces in China. All except a few provinces in China felt the shock of the earthquake wave[1)]. The Wenchuan Earthquake did have great impacts on daily life and economic activities in the earthquake-hit areas (YANG et al. 2008, LI et al. 2008). Official figures show that there are 68,636 people confirmed dead, 374,176 injured, 21 million buildings destroyed, and 4.8 to 11 million people left homeless in Sichuan province as a result of the Wenchuan Earthquake. That means that the Wenchuan Earthquake has been the deadliest one to hit China since the 1976 Tangshan Earthquake, which not only destroyed lives, but also did harm

1) China Earthquake Administration. An earthquake measuring 8.0 on the Richter scale struck Wenchuan County, Sichuan Province, China.

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to agricultural production, services, basic infrastructure, and so on. The Central Government of China announced that it would spend 1 trillion *yuan* over the next three years to rebuild homesteads ravaged by the Wenchuan Earthquake.

The Wenchuan Earthquake seriously damaged the ecological environment of the affected areas (Sichuan Provincial Government 2008, State Forestry Administration 2008). Giant panda, one of the few rare and endangered species in China, lives in a few mountain ranges of Sichuan, which were hit severely by the earthquake. The landslides and rock avalanches triggered by the earthquake are now seriously threatening giant panda (see Figure 1). A great numbers of landscape patches in the giant panda nature reserves have been destroyed due to the earthquake hit, as has been shown in changes of landscape within the red circle in Figure 1b. Its living conditions are the subject of great concern from the whole country, as well as all over the world. Although most of the giant panda nature reserves were located in the earthquake-hit area, there was less detailed information about to what extent giant panda was affected by this earthquake quite a long time after the earthquake event (State Forestry Administration 2008). It is one of the top priorities to estimate the impacts of the Wenchuan Earthquake on the ecological environment of the giant panda nature reserves.

Although we were greatly concerned about the living conditions of giant panda after the earthquake, its exact conditions were kept unknown for quite a long time. Among all the reports and studies on giant panda, there were mainly two opposite opinions about the living conditions of giant panda. One group of specialists thought that although the Wenchuan Earthquake had caused some damages on the ecological environment of its habitats, giant panda still possesses good condition[2)], while another group of specialists concluded that the giant panda nature reserves were seriously damaged, so the existence conditions of giant panda became worse. Because most of the roads leading to the giant panda nature reserves were destroyed by the earthquake and the succeeding secondary geological disasters, and the topographic conditions of the giant panda nature reserves were quite complicated, it was fairly hard to obtain an overall view of the exact conditions of giant panda. Fortunately, remote sensing technology was used as an efficient and effective alternative approach in this study. Based on the interpretation of the remote sensing images for the giant panda nature reserves in the earthquake-hit areas, the damages to the ecological environment of the nature reserves and the immediate impacts of the earthquake on its living conditions were estimated.

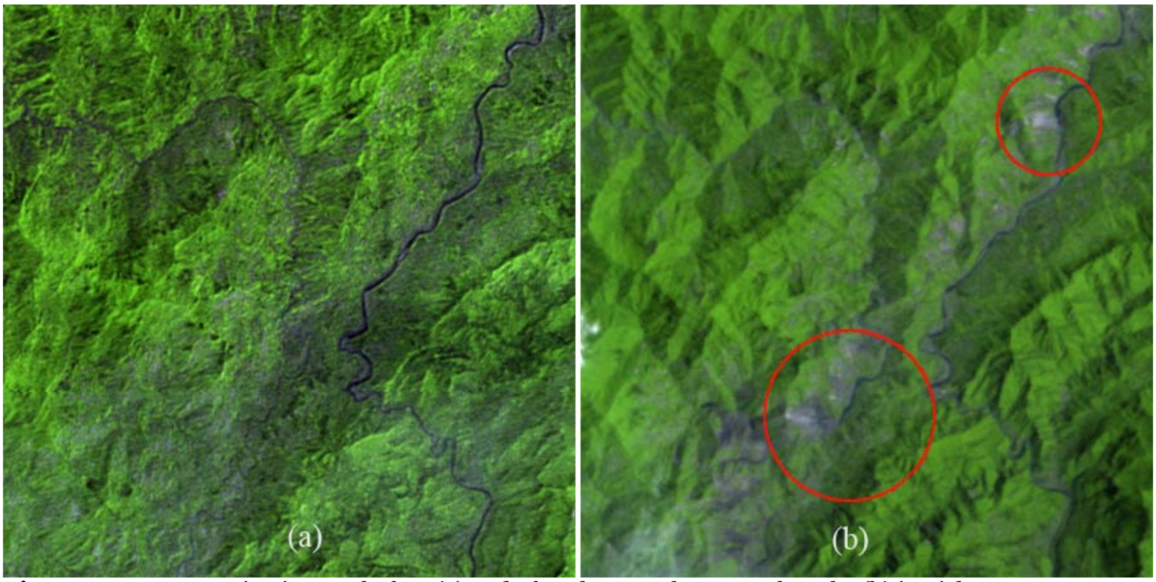

Figure 1 Remote sensing images before (a) and after the Wenchuan Earthquake (b) in Sichuan

2) Nanfang Daily, Living Report on Giant Panda after Wenchuan Earthquake, A12, 2008-7-13.

1 Study Area

The estimation of the impacts of the Wenchuan Earthquake on its hit areas was carried out in 49 giant panda nature reserves in 43 counties (see Figure 2), most of which are located in Sichuan, and a few in Gansu and Shaanxi. The earthquake-hit areas are rich in forests, and are humid and rainy in climate. There is a vertical zonation of the ecological conditions along elevation. The specific climatic and geological environments offer wild animals a most favorable living environment. Some rare animals, such as giant panda, golden monkey and antelope occur in the areas (CHENG et al. 1999). About 30 percent of the total giant panda individuals grow in these areas (YAN 2005). The living conditions of giant panda are quite unique, and have the following specific requirements: 1) the elevation ranging from 1,200 m to 3,800 m; 2) the slope lower than 45 degrees; 3) with dense vegetation and forests; and 4) with enough bamboo as giant panda's food (OUYANG et al. 2001).

2 Data and Methodology

The changes in the ecological conditions or the landscapes in the giant panda nature reserves in earthquake-hit areas were derived from the Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper (ETM) digital images from June 18, 2007 before the earthquake, and those from August 18, 2008 after the quake. Some auxiliary information on the damages to the landscapes there after the earthquake was obtained from the air photos taken by the Ministry of Land and Resources of China, and the reports released by the local governments and the management agencies. Elevation data were produced by interpolating the

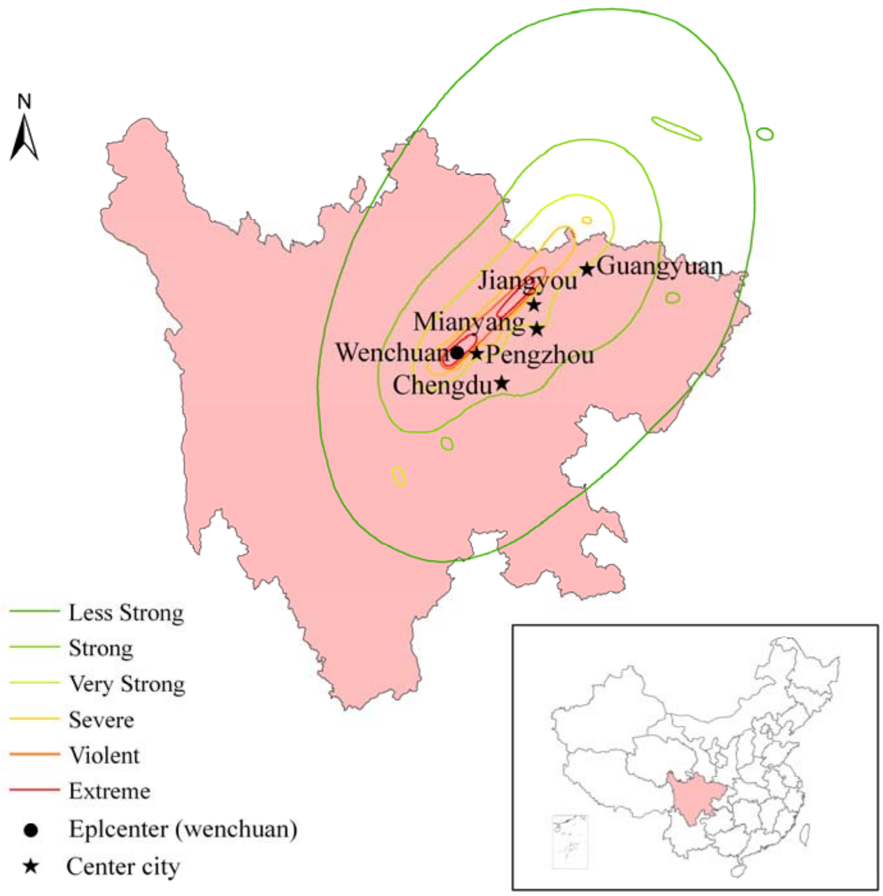

Figure 2 Location map of giant panda nature reserves in the earthquake-hit areas of Sichuan

vector data digitized from the national contour map into grids.

Remote sensing technology is increasingly recognized as a valuable post- earthquake damage assessment tool (Adams et al. 2004). Remote sensing imagery provides a detailed overview of the damages sustained. Based on a multi- temporal change detection algorithm for determining the location and severity of post-earthquake landscape damages, a rapid assessment method was introduced in this study (see Figure 3). After the interpretation of the remote sensing imageries, the location and severity of the damages can be rapidly identified and evaluated.

First, Landsat TM/ETM digital imagery of an earthquake area before and after the earthquake is acquired and preprocessed to remove cloud-fog cover using the homomorphic filtering method. Then the image distortion brought by radiant errors is cleared through radiometric calibration in which three procedures—remote sensor calibration, atmospheric correction, and topographic correction—are included. The procedure for remote sensor calibration mainly handles the incremental correction coefficient and deviation correction. The atmospheric correction procedure uses the empirical model to remove the effects of atmosphere on the reflectance values of images. As the affected areas are mostly mountainous, the procedure for topographic correction is carried out. Then, the false-color images are fused and produced. Next, the fused, false- color digital images are geo-referenced and projected into the Albers projection system with reference to the ground control points. Finally, the images are visually interpreted using manual tracing and on-screen digitization techniques, as well as visual interpretation, to detect changes in landscapes (see Figure 3). Depending on the sensor resolution, image color, shadow, size, texture, pattern, site and association, the land surface features are identified. Using ArcGIS (geographic information system) software and vector drawing tools, the land-use maps are created by overlaying the images before the earthquake onto the images after the earthquake (Kandeh et al. 2005). Most of the areas

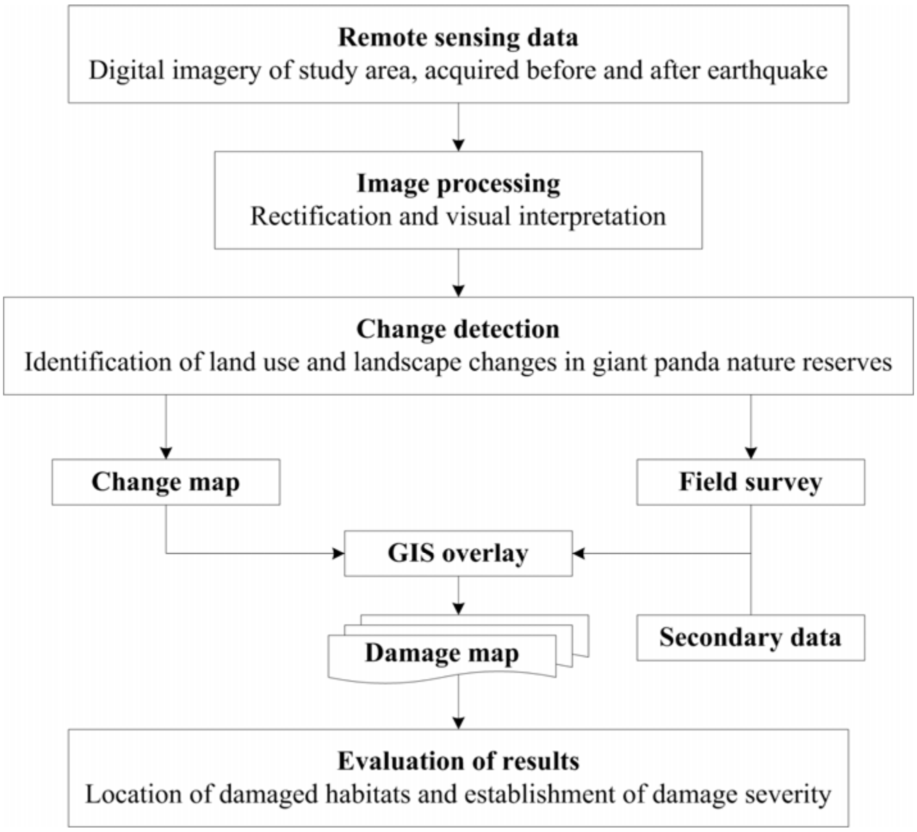

Figure 3 Rapid assessment method for evaluating the damages caused by earthquake

which were hit by coast, landslide, or debris flow aroused by earthquake became denuded. Change detection maps can be obtained by combining the two-date land-use data (prior to earthquake data and post- earthquake data). The field survey and other secondary data were also used. Afterwards, damage assessment maps were produced by overlaying the change detection map and survey data. The last step was to evaluate the results. Finally, based on the damage assessment map, the location and scope of the damaged giant panda habitats were displayed, and the severity of the damages was established.

According to the land-use classification system of Sichuan province, a scheme of visual interpretation for the giant panda nature reserves was used to classify the land-use information into six types: cultivated land, forestry area, grassland, built-up area, water area, and unused land (see Table 1). The aforementioned data was derived from 30-m by 30-m Landsat TM/ETM digital high-resolution images. Although it was not a completely new method, the efficiency of the visual interpretation served to reduce the overall classification error as the prior knowledge was incorporated into the whole process (LIU 1997, DENG et al. 2002, LIU et al. 2003). The average interpretation accuracy for landscape classification is around 82.9%, according to the field surveys. Forest is the most important land-use class for the panda in the study area, because it not only supplies food, but also provides habitats for panda. We validated the interpretation accuracy for the forest area (see Table 2), e.g., the accuracy for the forest before and after the earthquake was 93.43% and 97.30%, respectively.

In order to accurately reflect the true condition of the landscape of the giant panda nature reserves, we also used some other indicators in this study. We used FRAGSTATS to calculate a series of typical landscape indexes according to the interpreted information on land uses before and after the Wenchuan Earthquake, such as the number of patch habitats in the giant panda nature reserves, the patch density, the largest patch index, the largest shape index, and the mean patch area. FRAGSTATS is a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns. The original software was released to the

Table 1 The landscapes classified in this study

Landscape Type	Explanation
Cultivated land	Original data include both paddy and no irrigated uplands, which are aggregated into total cultivated land for this study.
Forestry area	Natural or planted forests with canopy cover greater than 30%; land covered by trees less than 2 meters high, with a canopy cover greater than 40%; land covered by trees with canopy cover between 10 and 30%; and land used for tea plantation, orchards, and nurseries.
Grassland	Land covered by herbaceous plants with grass cover greater than 5%, and mixed rangeland with shrub cover less than 10%.
Water area	Land covered by natural water bodies or land with facilities for irrigation and water reservation, including rivers, canals, lakes, permanent glaciers, beaches and shorelines, and bottomland.
Built-up area	Land used for urban and rural settlements, industry and transportation.
Unused land	All other lands.

Table 2 Summary of the accuracy validation for the forest area before and after the earthquake

Item		Forest area
Before earthquake	Number of selected patches	1,073
	Interpretation accuracy of forest area (%)	93.94
After earthquake	Number of selected patches	2,472
	Interpretation accuracy of forest area (%)	97.30

public domain in 1995 in association with the publication of the U.S. Department of Agriculture (USDA) Forest Service General Technical Report (McGarigal and Marks 1995). Now the program has been completely revamped. Based on the landscape indexes, we could determine the landscape changes and damage degree. The landscape fragmentation is an estimate of the environmental change in evolution and conservation biology (WANG et al. 1999). In addition, the landscape diversity index was used as an indicator to identify the landscape conditions and changes in the landscape structures of the giant panda nature reserves (Bystriakova et al. 2003). Thus, after evaluating the results by using the rapid assessment methods and the series of typical landscape indexes, we were able to estimate the impact of the Wenchuan Earthquake on giant panda.

3 Results

3.1 Spatial pattern of the geological disaster area

The remote sensing detection results and field survey data indicate that most of the geological disaster areas resulting from the Wenchuan Earthquake were located in the areas with elevation from 900 to 3,800 m, whereas the areas with elevations below 900 m and above 3,800 m were less damaged. After overlaying the remotely sensed landscape changes onto the surveyed or estimated earthquake damage maps and the rasterized elevation map, we could then delimit the coverage and intensity of the damages along with elevation gradient (hereafter referred to as elevation classes). The most heavily damaged geological disaster areas were at the elevation ranging from 1,300 to 3,000 m, which occupied 78.82 % of the total damaged area. That is, the geological disaster areas resulting from the Wenchuan Earthquake roughly coincided with the most active areas of giant panda's habitats (see Figure 4).

The distribution of geological disaster areas resulting from the Wenchuan Earthquake shows an obvious spatial differentiation pattern. Most of the geological disaster areas were located on the mountain slopes between 20 and 55 degrees, which occupied 88.12 % of all the disaster areas. However, the areas at a slope below 20 degrees and above 55 degrees were less damaged, and only accounted for a small part of the disaster areas (i.e., 7.75 % and 4.13 %, respectively) (see Figure 5).

3.2 Impacts of the Wenchuan Earthquake on the giant panda habitats

The decoded landscape information before and after the earthquake shows that large areas of

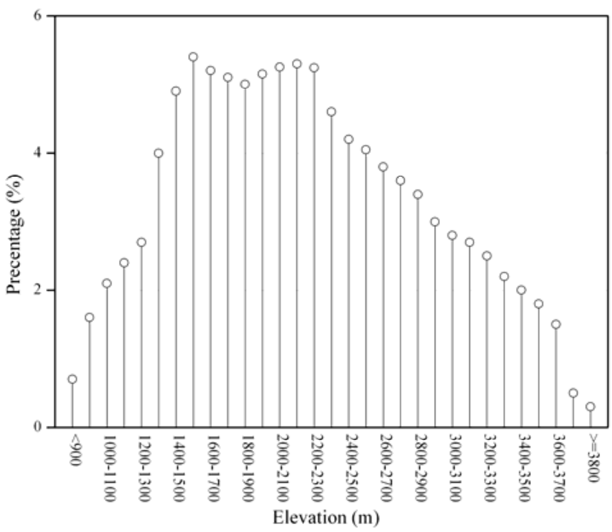

Figure 4 Distribution patterns of geological disaster areas after the Wenchuan Earthquake by elevation gradients

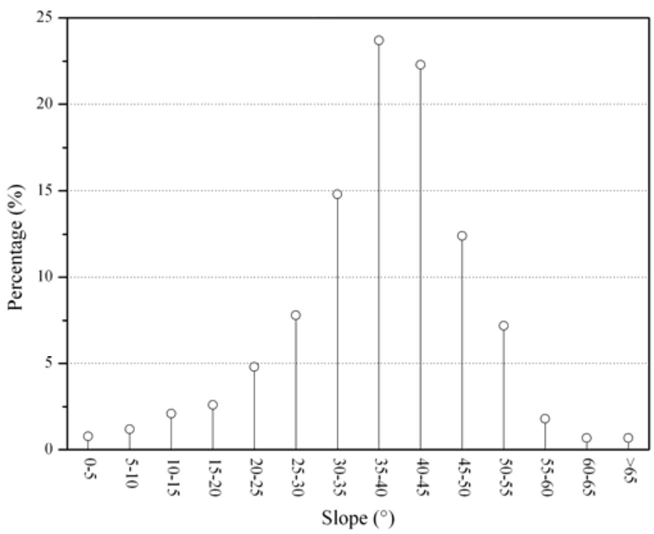

Figure 5 Distribution patterns of geological disaster areas after the Wenchuan Earthquake by slope gradients

Table 3 Summary of the damaged areas in the giant panda nature reserves by the Wenchuan Earthquake

Item	Habitat area (ha)	Area of patches (ha)	Patch density	Largest patch index	Largest shape index	Mean patch area (ha)
Before earthquake	480,331	3,753	0.42	25.52	48.8	164
After earthquake	395,262	28,908	2.16	8.34	76.63	56

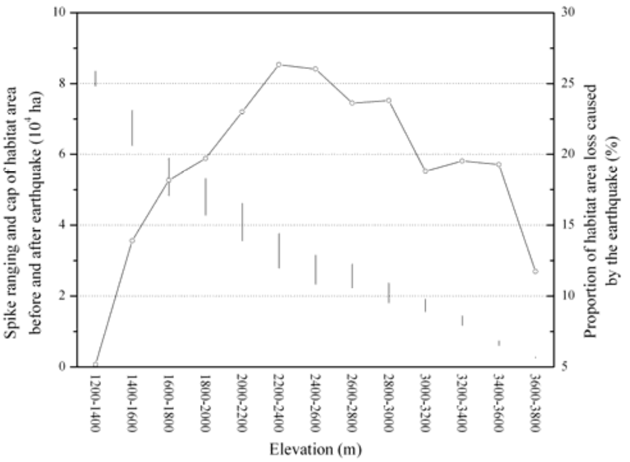

Figure 6 The lost area of the giant panda habitats in the nature reserves along the altitudinal gradient

cultivated land, forestry area and grassland were damaged, and the landscape fragmentation of the giant panda habitats was increased significantly. The landscape fragmentation index and diversity index of the giant panda habitats were calculated to identify the changes in the landscape structure of the giant panda habitats.

Based on the analysis of remote sensing images interpretation combined with field survey data, results indicate that the area of potential habitats of giant panda was about 480,331 ha, of which an area of 85,068 ha was totally lost because of the earthquake, accounting for 17.71 % of the whole area of the 49 giant panda nature reserves (see Figure 6).

The earthquake made the landscape fragmentation increased significantly. The area of the patches of the giant panda habitats totaled 3,753 ha before the earthquake, and then it increased to 28,908 ha after the earthquake by nearly 8 times. The patch density increased from 0.42 to 2.16. The mean area of the patches decreased from 164 ha to 56 ha accordingly (see Table 3). In fact, there were some limitations to derive these indices with Landsat 5 TM images, as its resolution was so coarse that some of the small areas might be ignored during the analysis.

In conclusion, the results from this research show that the Wenchuan Earthquake caused great damages to the giant panda habitats. A large fraction of landscape was affected and the damaged areas were sparsely distributed across all of the 49 giant panda nature reserves (see Figures 7 and 8).

3.3 Impacts on the forestry area

The conditions of the forests, especially those of panda's staple food, bamboo, are closely related to the living conditions of giant panda (Taylor et al. 1993, Keski et al. 2008). And the damaged forestry areas due to the earthquake would directly affect the growth of bamboo (QIN et al. 1993, OUYANG et al. 2000). One of the features of the forestry area in the giant panda nature reserves is the vertical zoning. In 1986, the SFA released a report stating that forest zone with an elevation lower than 1,600 m was evergreen broad-leaved forest, that from 1,600 to 2,000 m was mainly covered by the evergreen and deciduous broad-leaved mixed forest, from 2,000 to 2,600 m was mainly covered by coniferous and broad-leaved mixed forest, from 2,600 to 3,600 m was the subalpine coniferous forest, *Abies recurvata* and *Fargesia spathacea* Franch grew in large areas in the upper zone. The forest zone with an elevation above 3,600 m was alpine shrubs.

Interpretation of the satellite imagery showed that the landslides, debris flow and other geological disasters occurred mainly in the evergreen and deciduous broad-leaved mixed forest zone at an elevation from 1,600 to 2,000 m, where 28.77 % of the total area was destroyed, and also in the evergreen and deciduous broad-leaved mixed forest zone from 2,000 to 2,600 m, where

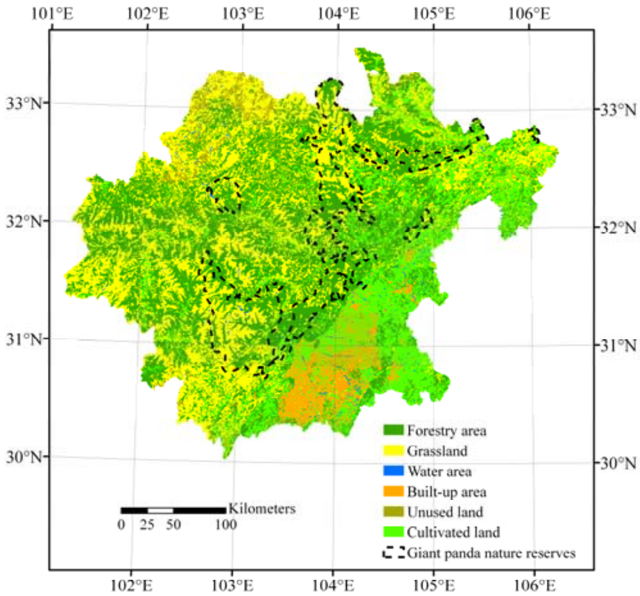

Figure 7 Landscape distribution map before the Wenchuan Earthquake

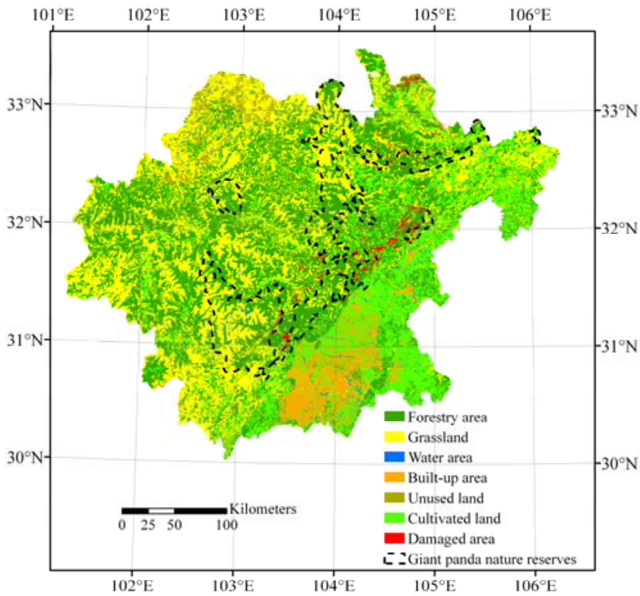

Figure 8 Distribution map of landscapes and damaged areas due to the Wenchuan Earthquake

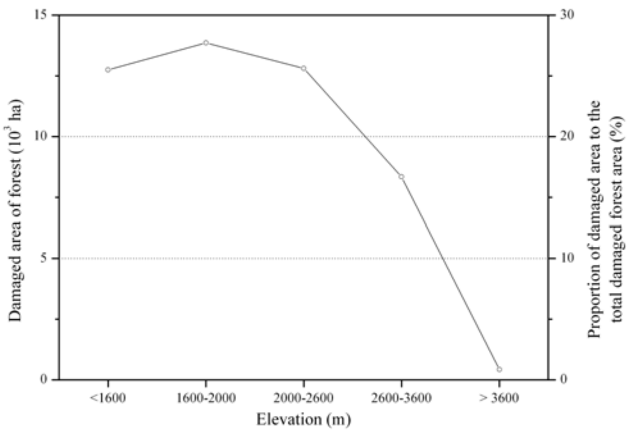

Figure 9 Damaged areas in different forest zones at various levels

26.59 % of its total area was affected. In giant panda's major living area, the forest zone with an elevation from 2,600 to 3,600 m, about 17.31 % of the total forest area was damaged. The damage to bamboo areas led to starvation of giant panda. The damage to the zone at an elevation above 3,600 m was not so serious, and only 420 hectares of the total forest area were damaged (see Figure 9).

As we previously mentioned, the remotely sensed estimation indicated that the Wenchuan Earthquake totally damaged 48,180 hectares of forest area. Judging by the above detection results, it was indicated that the loss of forest area in the giant panda nature reserves would definitely affect the living conditions of giant panda.

3.4 Impacts on the food supply for giant panda

Our research shows that the Wenchuan Earthquake not only caused damage to the giant panda nature reserves, but also produced certain impacts on its living conditions. As a result, the food supply for giant panda was affected to some extent. The loss of forest area and water area undoubtedly affected the food and water available for giant panda.

Most of the habitats of giant panda were located in the subalpine coniferous forest zone at an elevation from 2,600 to 3,600 m. The landslides, debris flows, and other geological disasters occurred mainly in this forest zone. At the same time, partial water sources were polluted or damaged, which might make more difficult for giant panda to access the drinking water. This affected the living of giant panda to some extent. However, preliminary research showed that the fraction of the damaged forest area was quite large as we mentioned above, and that the Wenchuan Earthquake damaged a large area of forests at elevations from low to high (see Table 4). Most of the water areas in the giant panda nature reserves were small lakes and streams. Thus, the damaged area was relatively small. Based on this, we concluded that although all these consequent changes after the earthquake would not cause heavy impacts on giant panda, but they would make great trouble for giant panda in a short term.

3.5 Impacts on the moving paths of giant panda

The Wenchuan Earthquake and the following secondary geological disasters blocked the moving paths of giant panda. The landsides and debris flows destroyed the original landscape, narrowed the free space for the activities of giant panda, and interdicted communications among giant pandas. The free space available to giant panda was also cut to a relatively small area, or isolated areas, which might restrict the activities of giant panda.

In addition, the detailed interpretation of remote sensing information showed that the earthquake and the secondary geological disasters caused the giant panda habitats increased to 28,908 ha in the 49 giant panda nature reserves, nearly 8 times more than those before the earthquake (see Table 3). Thus, the damaged area and the increased area of habitats with geological disasters would exert great effects on the moving space of giant panda, which restricted its movement.

4 Conclusion

Based on the rapid assessment methods, we estimated the detailed damage conditions caused by the Wenchuan Earthquake in the giant panda nature reserves. The earthquake caused major impacts on the spatial patterns of landscape types, and the relatively major damages to the giant panda nature reserves, thus disturbing the routine living activities of giant panda. A total forest area of 48,180 ha was damaged by the earthquake, and many moving paths were so blocked, all of which greatly affected the living conditions of giant panda. The landslides and debris flows destroyed the moving paths of giant panda and blocked the corridors of communications among giant pandas. In addition, the landscape fragmentation increased significantly, and the damages occurred across the entire area of all nature reserves.

This study also shows that the rapid assessment methods presented in this paper offer the information of damages rapidly. Furthermore, by using these rapid assessment methods, it may be envisaged how damage maps can provide the greatly-needed information to emergency responders and government departments, thus enabling loss estimation, supplying valuable information on the salvation and protection of giant panda, and immediately making the protection policies of giant panda after earthquakes. The rapid assessment method we used in this study undoubtedly still possess some limitations. For example, because of more and more requests for assistance during and after the earthquake, the precision of manual interpretation needed to be further improved, although they had already been proven to be the best among the analogous methodologies. Even so, we can improve them or correct them by conducting a detailed field survey and carefully interpreting the survey results.

On the basis of this research results, we strongly suggested that attention should be paid to the restoration of the giant panda nature reserves. We propose that a set of measures to restore and protect the ecological environments of the giant panda nature reserves should be prioritized to be set up. A more comprehensive estimation of the damages to the ecological landscapes in the giant panda nature reserves should be prepared. A prevention and warning system to monitor the changes in the giant panda habitats after earthquakes should also be established. Finally, a plan for long-term ecological environment restorations in the giant panda nature reserves should be worked out.

Acknowledgments

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