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REPORT

Effects of Natural Disasters on Conservation Policies: The Case of the 2008 Wenchuan Earthquake, China

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Abstract Conservation policies are increasing in response to human-induced ecosystem degradation, but little is known about their interplay with natural disasters. Through an analysis of satellite imagery and field data we evaluated the impacts of a devastating earthquake on forest recovery and avoided forest loss estimated to have been obtained by two of the largest conservation programs in the world. Results show that more than 10% of the forests in Wenchuan County, Sichuan province, China were immediately affected by the 2008 earthquake, offsetting some gains in forest cover observed since the enactment of the conservation programs. But without the enactment of these conservation programs, the combined effects of human disturbance and earthquake-induced landslides could have severely reduced the region's forest cover. The continuation—and enhancement—of incentives for participation in conservation programs will be important for reducing the environmental impacts of the combined effects of human disturbance and natural hazards not only in the study area but also in many disaster-prone regions around the world.

Keywords Conservation · Grain-to-Green Program · Natural disasters · Natural Forest Conservation Program · Payments for ecosystem services · Wenchuan Earthquake

INTRODUCTION

The desire to improve human livelihoods and at the same time conserve the world's biological diversity in the face of a growing human population has occupied scientists and policy makers for decades. On one end of this conundrum are policies aimed at increasing development but neglecting ecological considerations, resulting in biodiversity loss, landscape fragmentation, degradation of wildlife habitat, and an overall deterioration of natural ecosystems (Sala et al. 2000; Foley et al. 2005). At the other end are conservation policies based on legal prohibitions and sanctions that deter the use of natural resources, resulting in human displacement and impoverishment (Seno and Shaw 2002; Ghate 2003). Integrated approaches have also been developed that consider both ecosystem health and human well-being (Weladji et al. 2003), but their effectiveness at achieving both social and ecological goals is mixed (Browder 2002; Johannesen and Skonhoft 2005; Botha et al. 2006).

In recent years, forest cover has been recovering in many parts of the world in what has come to be known as the Forest Transition (Mather et al. 1998; Rudel 1998; Mather 2004). Modeled on the Demographic Transition (Caldwell 1976) in which increasing urbanization and industrialization led to declining birth rates in Europe and North America, forest transition theory posits that similar factors tend to result in growing forest cover, as marginal agricultural areas are abandoned and increasingly wealthy nations come to value natural landscapes and can afford to invest in biodiversity conservation. While the new forests are far from a perfect replacement for 'old growth' forests in terms of biological diversity, they are more likely to constitute habitat for wildlife than farmland (Perz 2007; Walker 2008). An important issue in the forest transition debate is the degree to which environmental policy serves as a catalyst to accelerate the recovery of forests. It has been suggested that the transition that took Europe and North America a century or more to accomplish may occur in other regions in just decades, due largely to government policies protecting forests and encouraging reforestation (Rudel et al. 2005; Mather 2007) through mechanisms such as financial incentives (e.g., payment for ecosystem services) (Daily and Matson 2008; Chen et al. 2009a).

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Owing to its enormous size—in land area and in human population—and the ability of its government to enact wide-ranging policy with relative rapidity, China presents an interesting case for analyzing the interplay among population, environment, and policy. While some major government policies in China in the twentieth century, such as the Great Leap Forward, are thought to have had considerable negative environmental consequences, others, such as the One-Child Policy, are sometimes credited with at least slowing the country's environmental problems (Liu 2010). According to the most recent statistics reported by the United Nations Food and Agricultural Organization, China started to experience net forest expansion (i.e., a forest transition) at the end of the twentieth century (Food and Agriculture Organization of the United Nations 2010). This 'turn of the corner' has taken place in the context of exceptionally rapid economic growth and urbanization (Liu and Diamond 2008). In fact, over the past three decades, China has been the fastest-growing economy in the world (Liu and Diamond 2008). As a result, people formerly involved in agricultural practices mainly for their own subsistence are 'modernizing' their livelihoods (Zhang 2010) and have thus become the labor force of non-farm enterprises (Song and Wang 2001; He 2004). Also, human population is becoming more concentrated, particularly around industrial enterprises and in cities (Song and Wang 2001; He 2004). In addition, the Chinese government has enacted, mainly in response to major floods in 1998, two of the largest forest conservation and restoration policies in the world (Uchida et al. 2005; Liu et al. 2008): (1) The Natural Forest Conservation Program (NFCP), which bans logging in natural forests and provides cash for local residents and others to monitor forests to prevent illegal harvesting, and (2) the Grain-to-Green Program (GTGP), which encourages farmers to return steep hillside cropland to forest by providing cash, grain, and tree seedlings. Under the NFCP, commercial harvesting of natural forests had ceased since 2000, and areas under the program had reached around 11 million hectares nationwide by 2005 (Liu et al. 2008). Through the GTGP, which was implemented in 2000, forest regeneration accelerated such that by 2006 net forest cover had increased 2% within the areas of GTGP implementation (Liu et al. 2008).

While urbanization, industrialization, and conservation policies may account for the net expansion in forest cover observed in many countries around the world, relatively little attention has been accorded to other factors, such as extreme events, which may also influence the scale and pace of forest transitions. The number of disasters associated with extreme events such as earthquakes or hurricanes has increased over the past several decades (Liu et al. 2007). In the short run, such disasters are likely to offset trends of forest expansion through direct losses in forest cover. Over time, these losses could persist if, for example, the conditions favoring the pre-existing transition (e.g., conservation programs) are not restored. However, it is also possible that such disasters could accelerate the pace of forest transition by providing opportunities for the implementation of more drastic conservation measures through disaster recovery and reconstruction efforts (Timms in press).

In this study we analyze the dynamics of forest cover in a remote region in the mountains of China, during a time period (1994–2008) characterized by economic growth, the enactment of two major conservation policies (i.e., GTGP and NFCP) and an extreme tectonic event (i.e., the May 12, 2008 Wenchuan Earthquake). We evaluate the influence of conservation policy on forest dynamics, assess the immediate effects of the earthquake, and discuss the long-term emerging and prospective consequences of post-earthquake recovery efforts.

STUDY AREA

With a total area of ca. 4,100 km^2, Wenchuan County is located in Sichuan Province, southwest China (Fig. 1). It is within one of the world's top biodiversity hotspots, the Southwest China hotspot (Myers et al. 2000; Mittermeier et al. 2004). The county is characterized by high mountains and deep valleys, with elevations between 790 and 6,000 m (Fig. 1). Together with this strong elevational gradient there is high variation in climate and soils, which leads to a diverse flora and fauna. Natural vegetation is dominated by evergreen and deciduous broadleaf forests at lower elevations (around 1,500 m) and subalpine coniferous forests at higher elevations (around 2,700 m). Besides providing habitat for many endangered species (e.g., *Ailuropoda melanoleuca*, *Neofelis nebulosa*, *Budorcas taxicolor*, *Rhinopithecus roxellana*, *Panthera pardus*), these forests also provide important ecosystem services such as wood (e.g., fuelwood, timber) and non-wood products (e.g., medicinal plants), soil and moisture retention, and carbon sequestration (Liu et al. 2008). Around 61% of the county is located inside two nature reserves: Wolong (ca. 2,000 km^2) and Caopo (ca. 550 km^2) (Fig. 1). The overwhelming majority of the region's inhabitants depend on agriculture for their livelihoods. Many are minorities, from the Tibetan, Qiang, Hui, and Yi ethnic groups, and the government is particularly sensitive in the application of social policies, such as birth control and relocation.

On May 12, 2008 a 7.9 M_w earthquake (8.0 on the Richter scale) struck the study area, followed by more than 30,000 aftershocks (Fig. 1). This earthquake was one of the worst natural disasters in China during the past 60 years, both in terms of human casualties and damage to

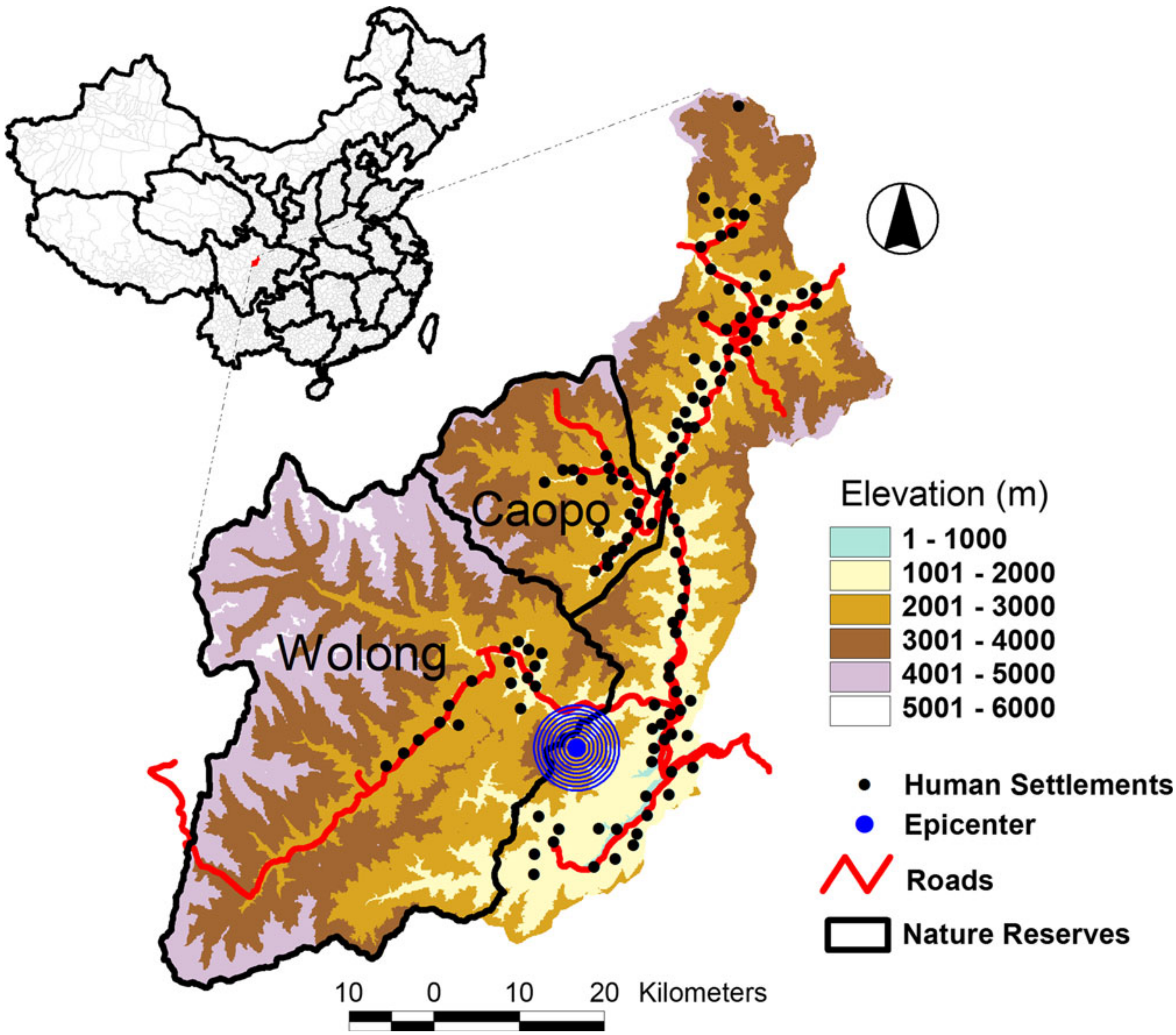

Fig. 1 Location, elevation, areas under nature reserves, human settlements and main roads of Wenchuan County in Sichuan Province, China. The location of the epicenter of the May 12, 2008 earthquake is also shown

infrastructure (Yin et al. 2009). The earthquake and its aftershocks triggered uncounted landslides, resulting in thousands of human casualties and the destruction of many forest areas, some of which constitute important habitat of the endangered giant panda (*A. melanoleuca*) and thousands of other animal and plant species (Liu et al. 2001; Fan 2009; Xu et al. 2009).

PRE-EARTHQUAKE FOREST COVER DYNAMICS

Landsat Thematic Mapper images acquired on June 26, 1994, June 13, 2001, and September 18, 2007 (Path 130, Rows 38–39 WRS-2) were used to analyze forest cover dynamics before and after the implementation of the NFCP and the GTGP in the study area. The 1994–2001 period was used to establish a pre-conservation-policy baseline, while the 2001–2007 period represented the dynamics following conservation policy implementation. Forest/non-forest maps were generated from each image via an unsupervised classification algorithm using the ISODATA technique (Jensen 1996). We used a maximum of 1,000 iterations with a convergence (the maximum percentage of the pixels in the image whose class values are allowed to be unchanged between iterations) specified at 0.99, producing an output of 100 spectral classes. We then applied a post-classification sorting method in which these spectral classes were merged into four information classes: forest, non-forest, clouds, and cloud shadows, through a combination of visual interpretation and information on land cover obtained from high spatial resolution multispectral imagery [i.e., four IKONOS multi-spectral scenes (4 × 4 m/pixel) acquired on August 31, October 3, and November 8 and 16 of 2000, respectively, and a Quickbird multi-spectral scene (2.4 × 2.4 m/pixel) acquired on November 23, 2007]. The few, small areas under cloud and cloud shadows were excluded from the analysis. Spectral classes associated with secondary forests were included in the forest cover class in the post-classification sorting procedure. Accuracy assessments of these maps were performed using ground truth points obtained in prior studies (Liu et al. 2001; Viña et al. 2007) during the summers of 1998 (209 points), 2000 (83 points), 2001 (83 points), and 2007 (593 points). The locations of these points were determined using real-time, differentially corrected GPS receivers. Overall forest mapping accuracy was 79.2, 78.2, and 82.6% for the 1994, 2001, and 2007 datasets, respectively. Part of the disagreement between the image classification and ground truth data obtained in the field could be attributable to changes in land cover between field and remotely sensed data collection dates.

Rates of forest cover change for the periods 1994–2001 and 2001–2007 were determined by:

$$R = \left[\left(\frac{A_e - A_b}{A_b} \right) \Big/ t \right] \times 100 \quad (1)$$

where R is the rate of change per year (in percent of initial cover), A_b is the forest cover area at the beginning of the period, A_e is the forest cover area at the end of the period, and t is the number of years for a given period (Viña et al. 2007). R takes negative (positive) values if the changes are due to losses (increases) in forest cover. It is important to underline the fact that the image classification procedure employed in this study produced 'hard' binary classes (i.e., forest and non-forest), but the forest cover losses or gains shown do not necessarily constitute complete land cover replacements (e.g., forest to grassland). On the contrary, forest cover losses or gains occur more often as a response to changes in biophysical characteristics, such as tree canopy closure, which could result from selective logging, tree recruitment, and individual tree canopy expansion, among others. These are represented as changes if they cross the multi-spectral threshold established between non-forest and forest by the image classification approach.

Forest cover dynamics observed between 1994 and 2001 were opposite from those observed between 2001 and 2007 (Fig. 2). While net forest loss was observed between 1994 and 2001 ($R = -1.4$), a net forest increase was observed between 2001 and 2007 ($R = +1.9$). This drastic change in the trend of forest cover dynamics (i.e., from a net loss to a net increase) is remarkable, given contemporary national trends. While China was experiencing a net increase in forest cover during the 1990s [R = +1.15 (Food and Agriculture Organization of the United Nations 2010)] the study region was still suffering a net forest loss. But this deforestation trend was reversed after 2001, reaching similar rates of forest cover gain as those reported for the entire nation during the 2000s [R =+1.91 (Food and Agriculture Organization of the United Nations 2010)]. The remarkable switch in forest cover dynamics observed in the study region coincided with a decrease in the amount of cultivated land, which occupied 1.6–1.8% of Wenchuan County before the year 2000 and decreased to ca. 0.8% in the year 2006 (Sichuan Statistics Bureau 2008).

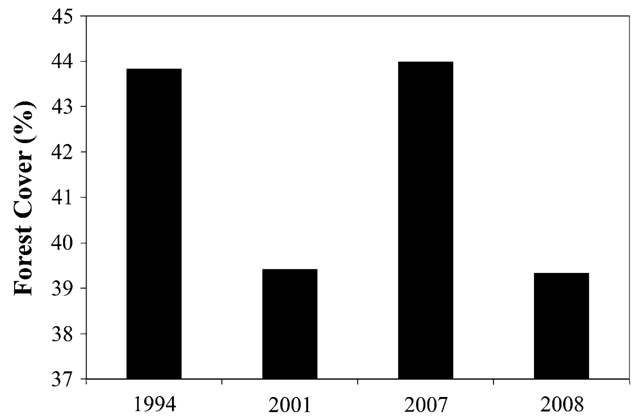

Fig. 2 Forest cover (%) in Wenchuan County during 1994, 2001, 2007, and 2008 (post-earthquake)

INFLUENCE OF CONSERVATION POLICIES ON FOREST COVER DYNAMICS

In the study area there was a net reduction of total population of about 1.2% per year between 2000 and 2007, but the number of households increased at an annual rate of about 2.3% during the same period (Sichuan Statistics Bureau 2008). Thus, while population declined, the number of households increased substantially. As households are directly associated with resource consumption (Liu et al. 2003), it is to be expected that the increase in household numbers would have had a negative effect on forest cover (e.g., due to the need for more land and construction materials, as well as fuelwood). However, a net increase in forest cover was observed during the same time period, together with a reduction of cultivated land, both of which occurred synchronically with the implementation of the NFCP and the GTGP. As we are not aware of any other major factors behind this shift, we argue that the implementation of these conservation policies constituted a strong catalyst of forest transition in the study area.

Previous studies have demonstrated that many forests in the study area had been converted to other uses through activities such as farming, fuelwood collection, construction of infrastructure, and tourism through the end of the twentieth century. These activities induced a gradual loss of forest cover in the years prior to the implementation of the NFCP and the GTGP (Liu et al. 2001; An et al. 2005; Viña et al. 2007). Under the NFCP, commercial timber harvesting was banned and the impacts of other human activities on the forest were reduced through local forest monitoring. For instance, households in Wolong Nature Reserve (Fig. 1) have been receiving annual compensation for monitoring activities since 2001. This annual compensation corresponds to ca. 900 Yuan/household (1 USD $\sim$ 8.2 Yuan in 2001), accounting for ca. 8% of the average household income in the year 2001, when implementation of the NFCP began in the reserve (Chen et al. 2009b). Local people were encouraged to purchase electricity with this payment in order to reduce their fuelwood consumption. In addition, GTGP enrollment began in 2000 (Chen et al. 2009a). Under this program landholders who converted part or all of their cropland to forest and kept the converted land forested received an annual payment (beyond the NFCP stipend) of 3,450 Yuan per ha. Local people responded positively to both of these conservation policies with the result that average annual household fuelwood consumption was reduced by ca. 40% between 2001 and 2006 (Chen et al. unpublished data). Thus, the ban on timber harvesting and a decline in the impacts of human activities should be expected to generate a reduction or even a reversal in the forest cover losses (Viña et al. 2007).

To assess the influence of conservation policy implementation on forest cover dynamics it is necessary to estimate the amount of forest loss and recovery that might have occurred without policy implementation. While no direct method is available for this, it can be approximated by establishing baseline rates of both forest loss and recovery observed prior to the implementation of the policies and project these forward as if they had not been implemented. We accomplished this through the development of a spatially explicit model capable of discriminating between forests that would not have existed in 2007 in the absence of conservation policies and forests that would likely have been there regardless. To this end, we selected a random sample of 3,000 pixels classified as forest in 1994 (most of which remained as forest in 2001, while the remainder experienced forest loss between 1994 and 2001) and 3,000 pixels classified as non-forest in 1994 (most of which remained as non-forest in 2001, while the remainder experienced forest recovery between 1994 and 2001). These randomly selected pixels were used to calibrate (using 2/3 of the pixels) and validate (using the remaining 1/3 of the pixels) logistic regression models [logistic procedure (SAS 2004)] for predicting the probability of forest loss and recovery during the 1994–2001 period. Some biophysical and demographic variables shown to be strongly correlated with forest cover dynamics in previous spatially explicit models (Southworth and Tucker 2001; Nagendra et al. 2003; McConnell et al. 2004; Southworth et al. 2004) were selected for use as predictor variables in these logistic regression models. These included elevation, slope, and aspect [converted into soil moisture classes (Parker 1982)], all derived from a digital elevation model acquired by the Shuttle Radar Topography Mission (SRTM) (Berry et al. 2007), together with distance to the nearest forest edge in 1994 and human population density. The latter was calculated as the density of human settlements (Fig. 1) within a 5-km radius (which corresponds to the maximum distance travelled by humans within the areas around households), weighted (multiplied) by the total human population in each settlement.

The regression models were validated with the receiver operating characteristic (ROC) curve (Hanley and McNeil 1982) using the reserved 1/3 of the random pixels. The ROC curve is a plot of the sensitivity values (i.e., true positive fraction) versus their equivalent 1-specificity values (i.e., false positive fraction) for all possible forest loss or recovery probability cumulative thresholds. The area under the ROC curve (AUC) is a measure of model accuracy that ranges from 0 to 1, where a score of 1 indicates perfect prediction, a score of 0.5 implies a prediction that is not better than random, and lower than 0.5 implies a worse than random prediction (Hanley and McNeil 1982). A standard for judging model performance based on AUC values (Swets 1988; Araújo et al. 2005) is: excellent ($AUC > 0.9$), good ($0.9 > AUC > 0.8$), fair ($0.8 > AUC > 0.7$), poor ($0.7 > AUC > 0.6$), and failed ($0.6 > AUC > 0.0$). Both logistic regression models were quite accurate in predicting the probabilities of forest loss and recovery, although the model of forest recovery exhibited a higher accuracy ($AUC = 0.880$) than that of forest loss ($AUC = 0.753$). This is not surprising since the location of forest recovery is conditioned by successional processes that are strongly influenced by biophysical factors, while forest loss is perhaps more strongly shaped by human land-use decision making, which is more difficult to model (An et al. 2005). The maximum likelihood estimates of the coefficients (Tables 1, 2) showed that elevation was positively related to the probability of forest loss but negatively related to the probability of forest recovery. This could be explained by the fact that forest areas in higher elevations were harvested during the 1990s while at lower elevations, which had been harvested earlier (i.e., during the 1970s and 1980s), forest recovery took place during the 1990s (He et al. 2009). Aspect, which was converted into soil moisture classes (Parker 1982), was negatively related to the probability of forest loss and positively related with the probability of forest recovery. As this relative scalar is associated in temperate regions with soil moisture in

Table 1 Maximum likelihood estimates of the coefficients of the predictor variables obtained in a logistic regression model to predict the probability of forest loss during the 1994–2001 period, as determined by classification of Landsat imagery acquired on June 26, 1994 and June 13, 2001

Variable name	Estimate	Standard error	χ^2	Pr > χ^2
Intercept	−0.6509	0.6135	1.1254	0.2888
Elevation	0.000706	0.000151	21.9027	<0.0001
Slope	−0.0219	0.0102	4.664	0.0308
Aspect	−0.0382	0.0149	6.5621	0.0104
Human density	0.00584	0.00225	6.721	0.0095
Distance to forest edge	−0.0264	0.0031	72.8546	<0.0001

Table 2 Maximum likelihood estimates of the coefficients of the predictor variables obtained in a logistic regression model to predict the probability of forest recovery during the 1994–2001 period, as determined by classification of Landsat imagery acquired on June 26, 1994 and June 13, 2001

Variable name	Estimate	Standard error	χ^2	Pr > χ^2
Intercept	1.6847	0.3826	19.3852	<0.0001
Elevation	−0.00054	0.000113	23.0173	<0.0001
Aspect	0.0532	0.0155	11.8096	0.0006
Human density	−0.00676	0.0019	12.6288	0.0004
Distance to forest edge	−0.0234	0.00279	70.4932	<0.0001

response to differences in solar illumination (Parker 1982), this result suggests that the probability of forest recovery is higher in mesic areas (e.g., north-facing slopes) while the probability of forest loss was higher in drier/sunnier areas (e.g., south-facing slopes). Human population density was positively related with the probability of forest loss while negatively related with the probability of forest recovery. As human population density constitutes a measure of the influence of humans on forests, this result agrees with other studies showing human influence to be associated with higher deforestation rates and lower forest recovery rates (Viña and Cavelier 1999; DeFries et al. 2004; Viña et al. 2004; Crk et al. 2009). Distance to the forest edge was negatively related with the probability of both forest loss and recovery. Therefore, the probability of forest recovery was higher closer to the edge of the forest as has been reported by other studies (Yamagawa et al. 2006). The probability of forest loss was also higher in areas closer to the edge of the forest, likely reflecting higher accessibility for activities such as fuelwood collection (He et al. 2009). While forest recovery was not significantly associated with slope, a negative relationship was observed between slope and the probability of forest loss. This suggests that forest losses have higher probability of occurring on gentler slopes which allow easier human access.

Maps depicting the probabilities of forest loss and recovery for the 2001–2007 period were then generated using the coefficients obtained for the 1994–2001 model (Tables 1, 2), but replacing the distance to forest edge observed in 1994 with the distance to forest edge observed in 2001. These probability maps were then converted into binary baseline forest loss and recovery maps by establishing a cumulative threshold such that the relative amounts of both of these dynamics per year observed in the 1994–2001 were projected to the 2001–2007 period. These baseline maps constitute an estimate of the amount and location of forest loss and recovery expected in the absence of the NFCP and the GTGP. Comparisons between the baseline and the actual observed outcomes constitute an approximation of the influence of the implementation of these policies on forest cover dynamics. On the one hand, the comparison of the baseline forest loss (i.e., derived from the logistic regression model developed for the 1994–2001 period and projected into the 2001–2007 period; Fig. 3A) with the observed forest loss (obtained from Landsat TM imagery acquired in 2001 and 2007, Fig. 3B) shows that about 12.8% of the forest cover present in 2007 could be attributable to avoided deforestation achieved through the implementation of conservation policies. On the other hand, the comparison of baseline forest recovery (i.e., derived from the logistic regression model developed for the 1994–2001 period and projected into the 2001–2007 period; Fig. 3A) with the forest recovery observed in the 2001–2007 period (Fig. 3B) shows that about 5.2% of the forest cover in 2007 may be attributable to forest recovery occurring as a result of the implementation of conservation policies. Therefore, the implementation of these policies could have accounted for as much as 18% of the total forest cover in 2007.

It is important to underline that the forest cover loss and recovery baselines obtained from the logistic regression models only constitute approximations. However, they not only allow for an estimation of the influence of conservation policies on forest dynamics but also for establishing their locations. For instance, as less than 3% of the area that experienced forest recovery during 2001–2007 was located in the GTGP area, most of the recovery that occurred during this time frame can be attributed to NFCP. This suggests that GTGP had a minor direct effect on the forest cover dynamics observed during the 2001–2007 period. This can be explained by the fact that most of the areas under the GTGP were being cultivated in 2000–2001 and require more than 6 years to develop sufficient tree canopy closure to be classified as forest (i.e., crossing the threshold from non-forest to forest). However, the GTGP may have exerted an indirect effect on the forest cover dynamics observed during the 2001–2007 period. For example, the GTGP program has been associated with an increase in

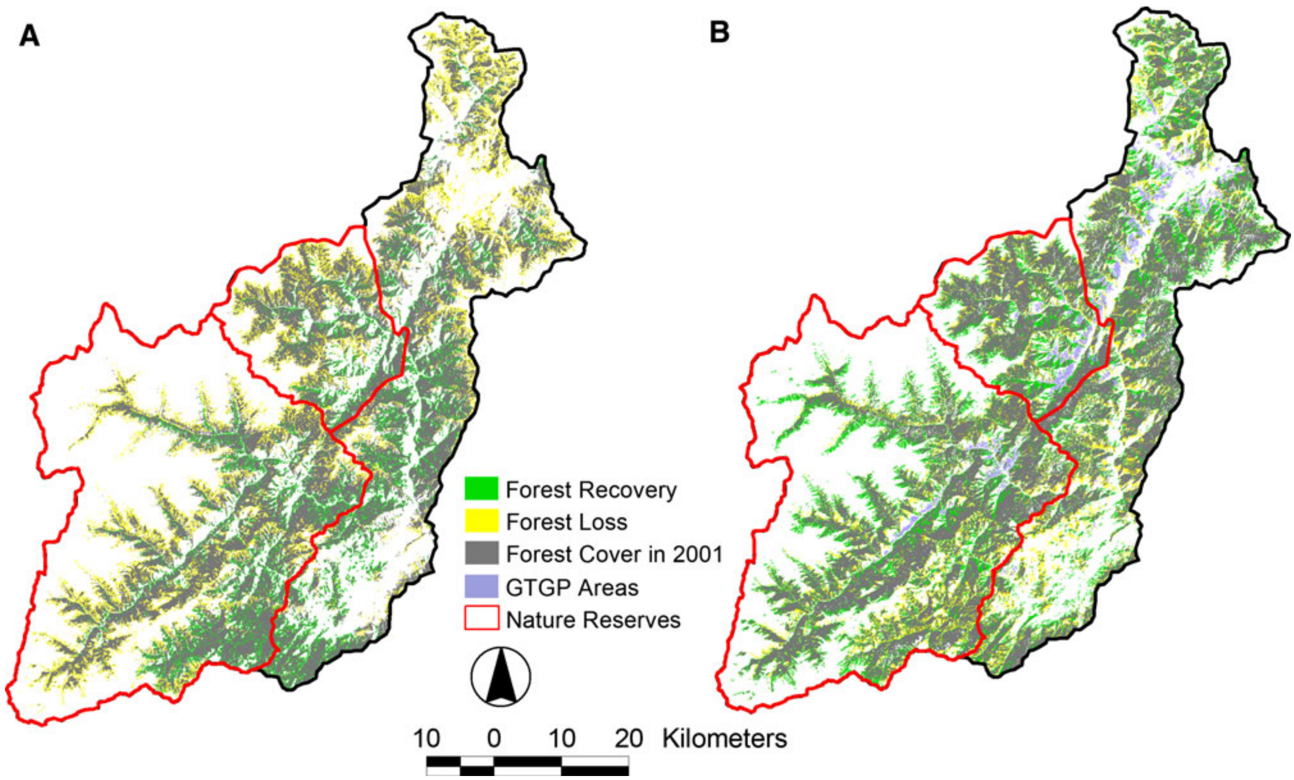

Fig. 3 Maps of Wenchuan County showing the locations of forest dynamics (i.e., no change, loss and recovery) during the 2001–2007 period as: **A** predicted by logistic regression models calibrated using the forest dynamics observed in the 1994–2001 period; and **B** observed through the classification of Landsat TM imagery acquired in June 13, 2001 and September 18, 2007. The boundaries of nature reserves are shown in red. The areas under the Grain-to-Green Program (GTGP) are also shown in (B)

rural–urban labor migration (Uchida et al. 2009), which might reduce human pressure on forests, enabling natural regeneration of disused cropland.

IMMEDIATE EFFECTS OF THE WENCHUAN EARTHQUAKE ON FOREST COVER

For the purpose of evaluating the immediate effects of the earthquake on forests, Landsat TM imagery acquired 2 months after the earthquake, on July 18, 2008 (Path 130, Rows 38–39 WRS-2) were classified into vegetated and non-vegetated areas (i.e., barren), clouds and cloud shadows, using a similar unsupervised classification procedure as that applied to the pre-earthquake imagery. Areas classified as forest in the 2007 data and as barren in the 2008 data were considered to be immediately affected by the earthquake. The locations of these damaged forest areas were then compared with the locations of forest recovery and avoided forest loss estimated to have resulted from the implementation of conservation policies, in order to estimate the immediate impacts exerted by the earthquake.

Our analyses indicate that around 192.6 km^2 of forest were damaged by landslides triggered by the Wenchuan earthquake and its aftershocks. This area corresponds to ca. 10.6% of the total forest cover in 2007 (Fig. 4) and represented an overall reversal in the amount of forest cover gain observed in the study area during the 2001–2007 period (Fig. 2). In addition, about 5.3 and 11.1% of the areas estimated as avoided forest loss and as forest recovery related with the implementation of conservation policies were damaged by earthquake-induced landslides, respectively (Fig. 4). While the damage to forest cover induced by the earthquake was quite extensive, without the implementation of conservation policies the combined effects of persistent human disturbance and earthquake-induced landslides would have further reduced the area of forest, leaving only about 33.5% of Wenchuan County under forest cover. This would have constituted a dramatic outcome compared to the ca. 39% actually observed after the earthquake (Fig. 2).

LONG-TERM EFFECTS OF THE WENCHUAN EARTHQUAKE ON CONSERVATION

The long-term effects of the earthquake will depend largely on how the area's inhabitants respond to the opportunities

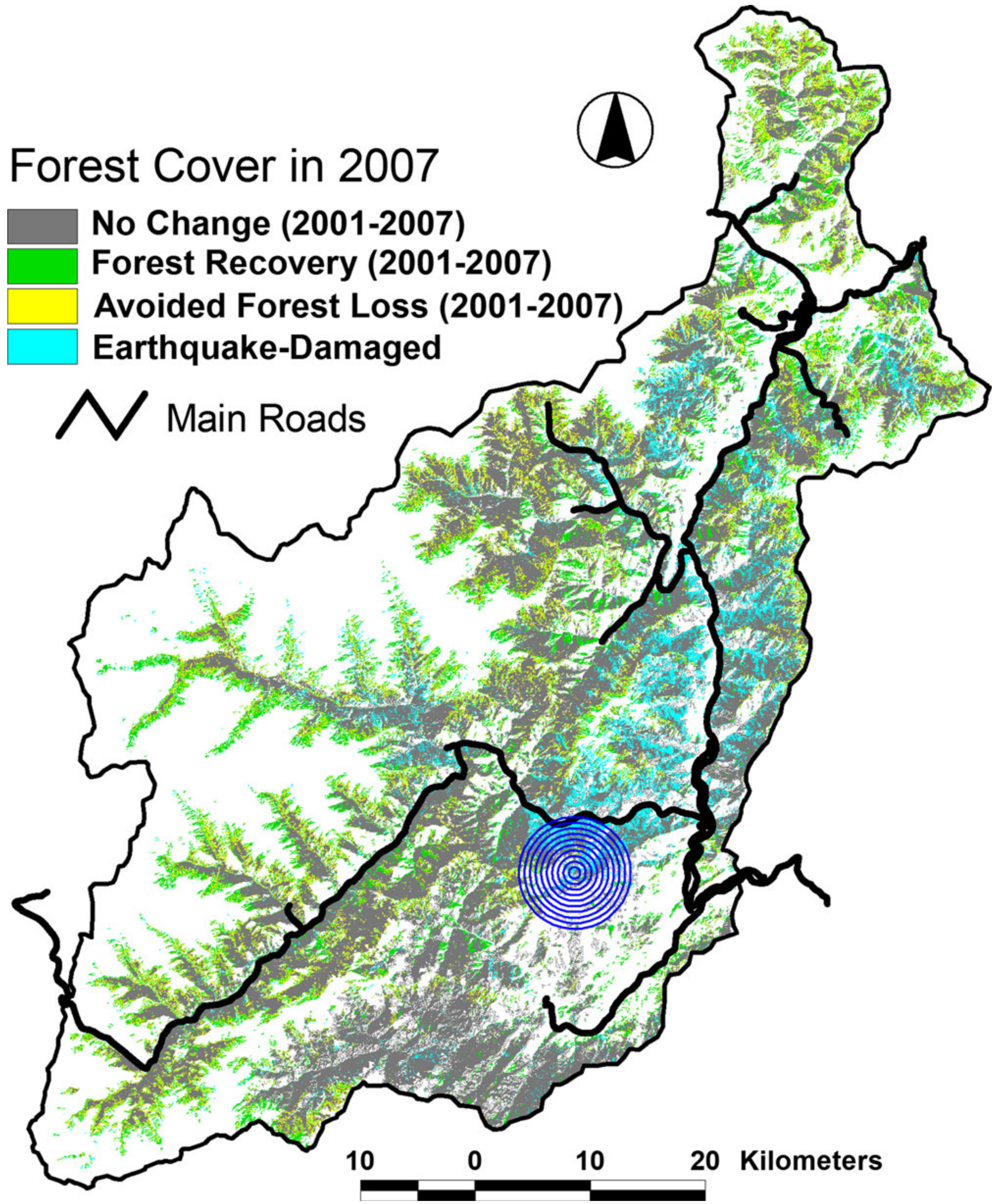

Fig. 4 Map of Wenchuan County showing the area of forest cover in 2007 sorted into forest areas related with the implementation of conservation policies (i.e., avoided forest loss and forest recovery), forest areas occurring even without the implementation of conservation policies (i.e., no change), and areas of forest immediately damaged by the Wenchuan earthquake. The location of the epicenter of the earthquake is also shown

and constraints they face, which in turn will be shaped by government reconstruction and rehabilitation actions. Even as rescue operations were under way, reconstruction plans were being developed (Sichuan Department of Forestry 2008; State Planning Group of Post-Wenchuan Earthquake Restoration and Reconstruction 2008; Wenchuan County People's Government et al. 2008). Based on the available information, we discuss these issues by focusing on the plans for the Wolong Nature Reserve, a protected area that makes up almost half of the study area (Fig. 1).

The construction of new housing near the main highway in the Reserve (Fig. 1) is currently well under way, offering residents improved access to public amenities and employment opportunities in exchange for relinquishing their agriculture-based livelihoods. Should large numbers of residents avail themselves of this new arrangement, the Reserve could witness more abandonment of farmland and subsequent regeneration of forest cover, especially if the pre-existing incentive programs for tree planting and forest monitoring continue or are enhanced. This could constitute a significant gain for biodiversity conservation. But while human relocation may lead to accelerated achievement of conservation goals, it is important to recognize that there are always tradeoffs because some solutions may work against the interests of the people who already suffered the most from the disaster (Timms In press). Thus, we are less certain about the prospects for the local residents, since there is little industry in the Reserve, and wage employment will likely be restricted to the tourism sector. Our previous study shows that, like in many other places around the world, the benefits from tourism in the Reserve are quite unequally distributed, with the majority of the benefits accruing to external investors, rather than local residents (He et al. 2008). We hope that the reconstruction efforts in Wenchuan will avoid these pitfalls, offering options to local residents for secure livelihoods. The continuation—and enhancement—of direct incentives for participation in conservation programs will be an important part of a win–win solution that improves human well-being while insuring the protection of the region's precious biological diversity.

CONCLUSION

Through evaluating the dynamics of forest cover in a remote mountainous area of China during a period of rapid economic growth, major conservation policy enactment and the occurrence of an extreme natural disaster, we found a complex interplay among these different forces that shape human activities and their influence on forest cover outcomes. These results are important not only for the study area but also for many other biodiversity hotspots around the world that are disaster-prone and are exposed to high human pressures (Cincotta et al. 2000; Liu et al. 2003). Over half of the areas considered hotspots of tectonic activity (Dilley et al. 2005) are within biodiversity hotspots. It has been argued that tectonic activity over long geological time periods could partially explain the occurrence of high biodiversity in some of these hotspots (Kathuria and Ganeshaiah 2002). But when massive earthquakes are combined with continued human disturbance this constitutes a serious conservation challenge. Thus, we suggest that conservation investments in these areas of spatial congruence of high biodiversity and tectonic activity be accorded priority. Such investments should always pay close attention to the well-being of local inhabitants and facilitate their active participation in conservation activities.

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