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REPORT

# Balancing urban growth and ecological conservation: A challenge for planning and governance in China

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**Abstract** China has high biodiversity and is rapidly urbanizing. However, there is limited understanding of how urban expansion in the country is likely to affect its habitats and biodiversity. In this study, we examine urban expansion patterns and their likely impacts on biodiversity in China by 2030. Our analysis shows that most provinces are expected to experience urban expansion either near their protected areas or in biodiversity hotspots. In a few provinces such as Guangdong in the south, urban expansion is likely to impinge on both protected areas and biodiversity hotspots. We show that policies that could facilitate the integration of natural resource protection into urban planning exist on paper, but the prevailing incentives and institutional arrangements between the central and local governments prevent this kind of integration. Removing these obstacles will be necessary in order to safeguard the country's rich biodiversity in light of the scale of urbanization underway.

**Keywords** Biodiversity · Nature reserve · Urbanization · Urban planning · Economic development · Land-use planning institutions and governance

## INTRODUCTION

China is among the most biologically diverse countries in the world. It ranks third globally in terms of flowering plant (angiosperms) diversity and among the top ten in terms of mammalian, avian, or amphibian diversity (McNeely et al. 1990). Over a million square kilometers of the country is in one of four biodiversity hotspots that are home to significant diversity of endemic species. As of 2009, the country had 2541 nature reserves, covering almost 15 % of its territory (Xu et al. 2012). Although the first of these nature reserves was established by the Chinese central government in 1956, their number has only increased substantially over the last two decades. These nature reserves, which are also internationally recognized protected areas (PAs), are home to over 300 threatened species of wild animals and about 130 species of rare and threatened species of wild plants (Xu et al. 2012).

Not only is China biologically diverse, it is also undergoing large-scale urbanization. Between 2000 and 2030, the urban population of China is expected to increase by about 400 million (UN 2012), and China will be the first country to have an urban population of 1 billion, a threshold that is expected to be crossed in the middle of this century. These demographic changes underway are paralleled by the physical expansion of urban areas. Between 2000 and 2030, the urban land area in China is expected to increase by almost 400 % (Güneralp and Seto 2013), compared to the projected growth of over 100 % in its urban population (UN 2012). The nearly 340 000 $km^2$ increase in urban land during this period will be the largest in the world.

Recently, China's State Council issued a new and ambitious urbanization plan that would have about 60 % of the country's population in urban areas by 2020, up from 52 % in 2012, and would result in the urban population increasing by about 100 million in less than one decade (China State Council 2014). Thus, although the rate and magnitude of urbanization in China over the past three decades have been significant, the country has not yet completed its urban transition and is very likely to experience more large-scale urban changes in the next decade.

The impacts of urbanization on biodiversity are complex and multifold. Urban expansion and associated land changes can fragment or destroy habitats (McKinney 2002), thus adversely impacting native species dispersal (Bierwagen 2007). Urbanization may increase species richness, but it can also facilitate colonization by introduced species often at the cost of native species (McKinney 2002, 2006). The

construction of transportation infrastructure can also be destructive (Forman and Alexander 1998). A recent study shows that a global strategy for road building is necessary in order to avoid large-scale and irreversible negative impacts on biodiversity and ecosystem services (Laurance et al. 2014). Another consequence of urban land change is the emergence of novel habitats within urbanized areas (Kowarik 2011) that often have altered ecological processes compared to the native ecosystems that they replace (Shochat et al. 2006). Several studies have also documented the fragmentation and loss of habitats in China as a result of rapid urbanization. Especially along the coast, many ecosystems have been destroyed due to construction and development activities (Zhao et al. 2006; Wang et al. 2009). Several biogeographic regions in eastern China are already severely fragmented (Li et al. 2010). Even further inland, where urban growth is slower than on the coast, development continues to impact ecologically sensitive areas (Li 2012). Thus, in spite of the proliferation of PAs, the expansion of urban areas continues to threaten habitats, which are critical for conservation of biodiversity (Lü et al. 2011).

Although case studies provide in-depth information about the impacts of urbanization on habitats and biodiversity at specific sites, they are both too few in number and sparsely distributed geographically to generate a comprehensive and coherent understanding of the relationship between urbanization and its impacts on biodiversity. There is only one study on China that estimates the amount of habitat lost due to urban expansion across the country (He et al. 2014). According to He et al. (2014), the country lost significant amounts of various habitats due to urban expansion over the past two decades and these losses were especially widespread in the Pearl River Delta in southeast China. Most existing studies evaluate past and current impacts of urbanization on China's biodiversity; there have been only a couple of studies that assess the implications of future urban expansion for habitats and biodiversity. One study, based on population projections, predicted that proximity of urban areas to the PAs in China will dramatically increase by 2030 (McDonald et al. 2009). Another study forecasts direct impacts of urban expansion on biodiversity in China alongside the rest of the world (Güneralp and Seto 2013). Neither of these studies elaborates on how the forecasted impacts vary across the country and on their policy implications.

The extent to which urbanization impacts biodiversity depends on the level of synergy among land-use, conservation, and urbanization policies and their effective implementation (Reed et al. 2014). Nevertheless, the issue of effective governance of land for conservation of biodiversity remains challenging even in more developed countries (Wade and Theobald 2010) due to such governance challenges as the fragmented jurisdictions of several administrative bodies (Shafer 1999). The stakes are arguably higher for an emerging economy such as China that faces the challenge of balancing high rates of industrialization and urban expansion with preservation of the country's rich biodiversity (He et al. 2014).

Here, we examine urban land-cover changes and their impacts in and around habitats that are critical for biodiversity across China. We also evaluate land-use policies, urban development strategies, and their potential for shaping urban outcomes in the country. Specifically, we ask: How will urbanization affect land near PAs and in biodiversity hotspots across Chinese provinces? What are the implications of future urban expansion for biodiversity conservation across different regions of the country? To what extent can urban and land-use governance and institutions effect more sustainable urban outcomes that also preserve the country's rich biodiversity? To address these three questions, we use a probabilistic simulation framework to forecast urban expansion out to year 2030 near the International Union of Conservation of Nature (IUCN)-designated PAs and in biodiversity hotspots across China.

## MATERIALS AND METHODS

Our forecasts of the growth in urban land in China use probabilistic projections of population and economic growth in the country, the two major drivers of urbanization (Liu et al. 2005; Angel et al. 2011). In addition, we also incorporate several spatial variables relevant for urban land change to forecast where the additional urban land will appear. There are uncertainties in how the population and economy of the country will change as well as where land change occurs. Our approach in this study follows a probabilistic framework presented elsewhere (Seto et al. 2012; Güneralp and Seto 2013) and accounts for these uncertainties in analyzing the potential implications of urban land expansion on habitats and biodiversity in China.

Our analysis creates 1000 spatially explicit forecasts of urban growth out to 2030; it is based on Monte Carlo techniques and consists of two phases. In the first phase, we fit probability density functions (pdfs) for population and GDP projections for China. Based on these probabilistic projections, we then generate 1000 realizations of aggregate amounts of urban expansion. In the second phase, we use a land change model to forecast the spatial distribution of urban expansion in each realization. The model is based on a well-established spatially explicit grid-based land change model, GEOMOD (Pontius et al. 2001). Our model uses slope, distance to roads, population density, and land cover as the primary drivers of land change and allocates geographically across the country each realization of urban expansion from the first phase of the analysis.

We first analyze the spatial distribution of urban land *circa* 2000 in and near PAs as well as in biodiversity hotspots within the country. For this purpose, we use the MODIS v5 land cover product (Schneider et al. 2009) to quantify the spatial distribution and extent of urban land *circa* 2000. Urban areas in MODIS v5 are defined as places predominantly (>50 %) covered by the built environment. We also use the 2010 World Protected Area Database (WDPA 2010) and the global biodiversity hotspots dataset (Myers et al. 2000; Mittermeier et al. 2004). The PAs designated by the IUCN have clearly defined boundaries under legal protection, and they officially serve the purpose of long-term conservation of nature with associated ecosystem services and cultural values (Dudley 2008). The biodiversity hotspots, home to many endemic species facing threats of habitat loss and degradation, are one of several biogeographic templates for setting conservation priorities (Brooks et al. 2006).

We include only the terrestrial PAs in our analysis; we quantify the amount of urban land in PAs and in concentric buffer zones around PAs up to a distance of 50 km from the perimeter of PAs by province, around year 2000. We assume 50 km is a reasonable first-order estimate to capture ecological interactions between a PA and its surroundings (DeFries et al. 2005). To analyze the likely direct impact of urban expansion near PAs and in biodiversity hotspots, we use the output from the probabilistic forecasts of urban expansion in the country for 2030. We assume full enforcement of formal regulations that do not permit urban expansion within the boundaries of the PAs.

## RESULTS

### Urban land in China: *circa* 2000 and as forecasted in 2030

A more recent urban extent map for China produced using the same methods as in our input urban extent map is not yet available. Absent such a map that would allow an assessment of the accuracy of the urban expansion forecasts, we conducted a preliminary comparison of the forecasts on two urbanizing regions in China (one on the coast, one inland) to the corresponding maps that show the growth of urban areas from 2001 to 2010 using a recently developed global index of urban areas, the Vegetation Adjusted NTL Urban Index, or VANUI (Zhang et al. 2013). The index uses a combination of data from MODIS and night-time light (NTL) data from the Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS) to map urban areas. With the caveat that the source data for the VANUI change maps and our forecasts are different, there is broad agreement between the observed and forecasted patterns of urbanization (Fig. 1). The biggest difference is the more compact patterns of urban expansion in the forecasts compared to the observed in the VANUI maps. In addition, the forecasts indicate urban expansion in places that did not experience such change by 2010 according to the VANUI maps (for example, southeast Sichuan). However, considering that the VANUI change maps are for 2001–2010 whereas the forecasts reflect the change from 2000 to 2030, these disagreements may also be indicative of further urban expansion in those places from 2010 to 2030.

China had about 80 000 $km^2$ of urban land *circa* 2000. Guangdong, Henan, Hebei, and Shandong were the provinces with the largest amounts of urban land—over 6000 $km^2$ each (Fig. 2). In Guangdong, the Pearl River Delta underwent large-scale urbanization as a result of economic reforms instituted in late 1970s. Henan, Hebei, and Shandong occupy the fertile and populous North China Plain that has long been an important core region of Chinese civilization with many urban centers. Together, these four provinces accounted for over one-third of total urban land on just 5 % of the land in the country. Between 2000 and 2030, urban expansion is forecasted to continue along the coast and across the central provinces (Figs. 2, 3) but substantial urban expansion is also forecasted in specific regions in the western provinces. The largest percentage increases are forecasted for those provinces that occupy the coastal and alluvial plains in-between and along the banks of Yellow River and Yangtze River. In the interior, Sichuan Province is forecasted to experience large increases in its urban land cover and will have the largest urban land area in the interior of the country. In total, we forecast that urban land in China will reach about 380 000–470 000 $km^2$ by 2030. This corresponds to about 400 % increase in urban land over 30 years. In comparison, the forecasted increase in urban land across the world is reported elsewhere to be slightly over 300 % (Güneralp and Seto 2013).

### Urban land within and near PAs *circa* 2000

In China *circa* 2000, nearly 4500 $km^2$ of the terrestrial PAs with IUCN status were already urbanized. This corresponds to over 5 % of total urban land in the country. Much of these urbanized PAs were scattered along the coastal regions of the country where the spatial concentration of both PAs and urban areas are particularly high (Fig. 4a). Nonetheless, it is Yunnan, a province exceptionally rich in biodiversity in the southwest of the country that had the most urban land in its PAs (Fig. 5). The provincial capital Kunming, which is almost completely located within the Dianchi PA with an IUCN category VI designation, accounted for most of this urban land. Overall, the urban land in Yunnan's PAs corresponded to about a quarter of

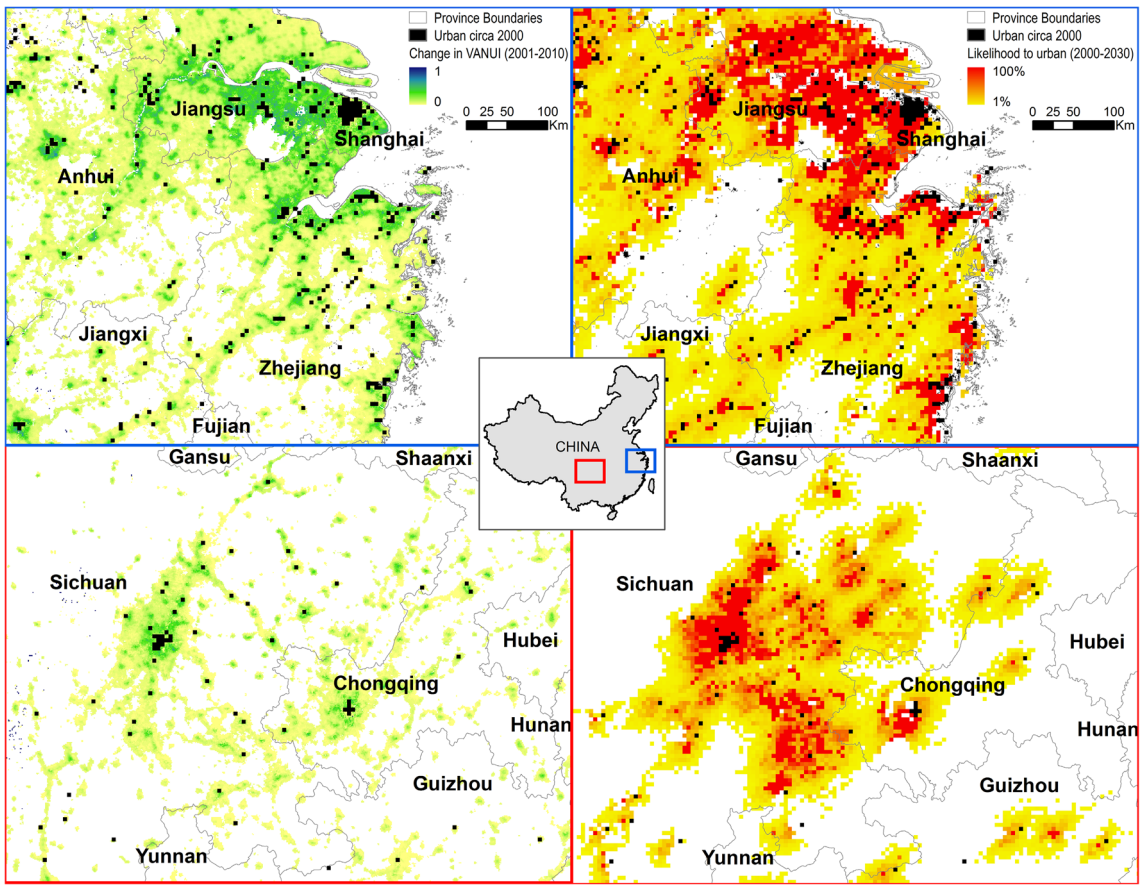


**Fig. 1** The comparison of urban expansion forecasts from 2000 to 2030 to changes in VANUI from 2001 to 2010 for two rapidly urbanizing regions in China

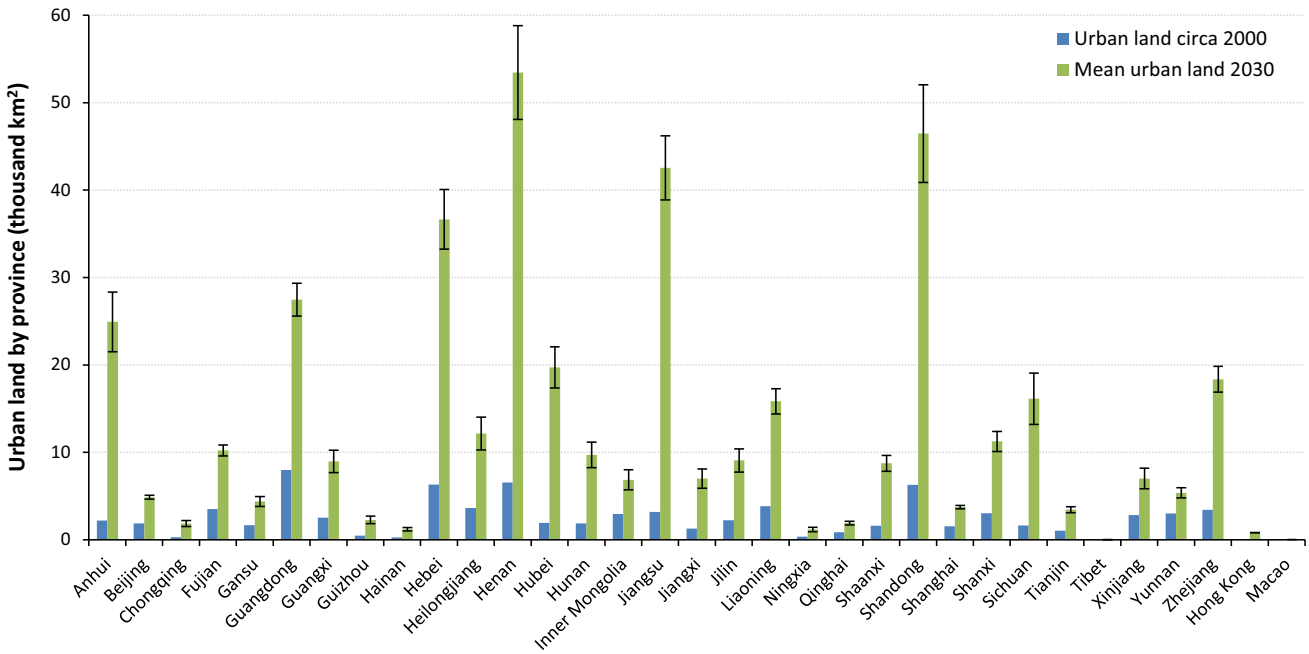


**Fig. 2** Urban land *circa* 2000 and forecasted mean urban land in 2030 by province. *Error bars* show one standard deviation

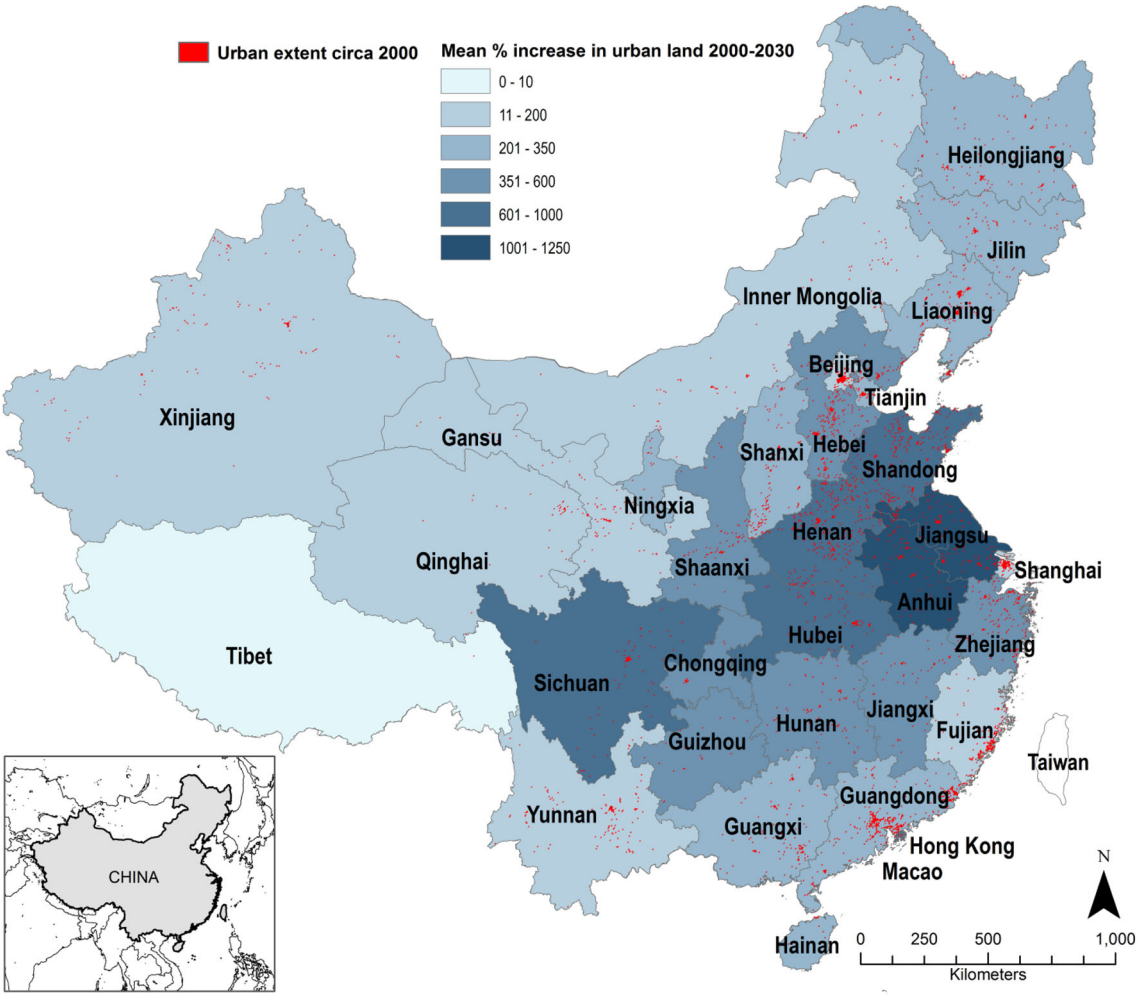


**Fig. 3** Forecasted mean percent increase in urban land between 2000 and 2030 by province

the total urban land in the province (Figs. 2, 5). Chongqing, on the other hand, had the highest percentage of its total urban land in its PAs—over 30 %. In Yunnan, most urban land was clustered around its capital Kunming that is the economic as well as the administrative center of the province. Likewise, in Chongqing, one of the four direct-controlled municipalities in China, the urban land was concentrated around its central districts that include the administrative seat of the municipality.

Across China, the total urban land within 50 km of the PAs was 60 000 km$^2$ *circa* 2000, corresponding to almost three quarters of all urban land in the country. The patterns of urban land near the PAs show large variations across the provinces (Fig. 5). The amount of urban land in close proximity to PAs was the largest in Guangdong, the province that borders both Hong Kong and Macau and one of the few regions that spearheaded the urban and economic development of China in early 1980s. Overall, more than 80 % of the provinces had most of their urban lands within 50 km of their PAs *circa* 2000. For China as a whole, these proportions remain virtually the same for 2030.

## Urban land within biodiversity hotspots *circa* 2000

Large areas of four biodiversity hotpots (Myers et al. 2000; Mittermeier et al. 2004) are located within China's borders: Himalaya, Indo-Burma, Mountains of Central Asia, and Mountains of Southwest China (Fig. 4a). In 2000, about 13 % of the total urban land in China—a little over 10 000 km$^2$—were located within these hotspots (Table 1). The urban land in Indo-Burma hotspot constituted 90 % of the total urban land across all four biodiversity hotspots in the country *circa* 2000 (Table 1). This percentage increases only slightly by 2030. The hotspot also extends across Guangdong province, which accounted for more than two-thirds of the urban land in this hotspot (Fig. 4a; Tables 1, 2). Around 2000, most of this urban land was located in and around the Pearl River Delta that had been rapidly urbanizing in the

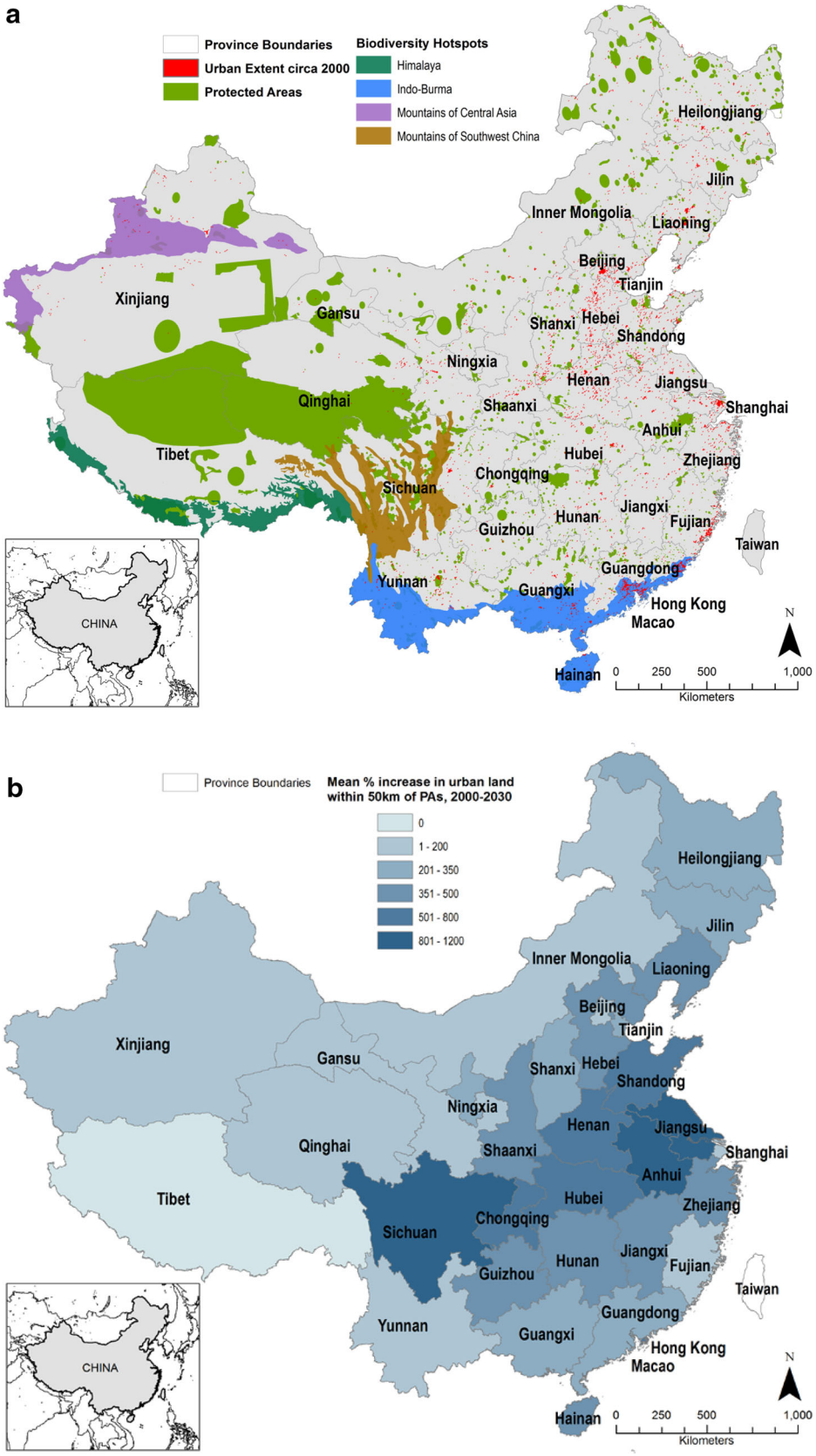


**Fig. 4** **a** Urban extent *circa* 2000, PAs, and biodiversity hotspots in China, **b** Forecasted mean percent increase in urban land near PAs between 2000 and 2030 by province

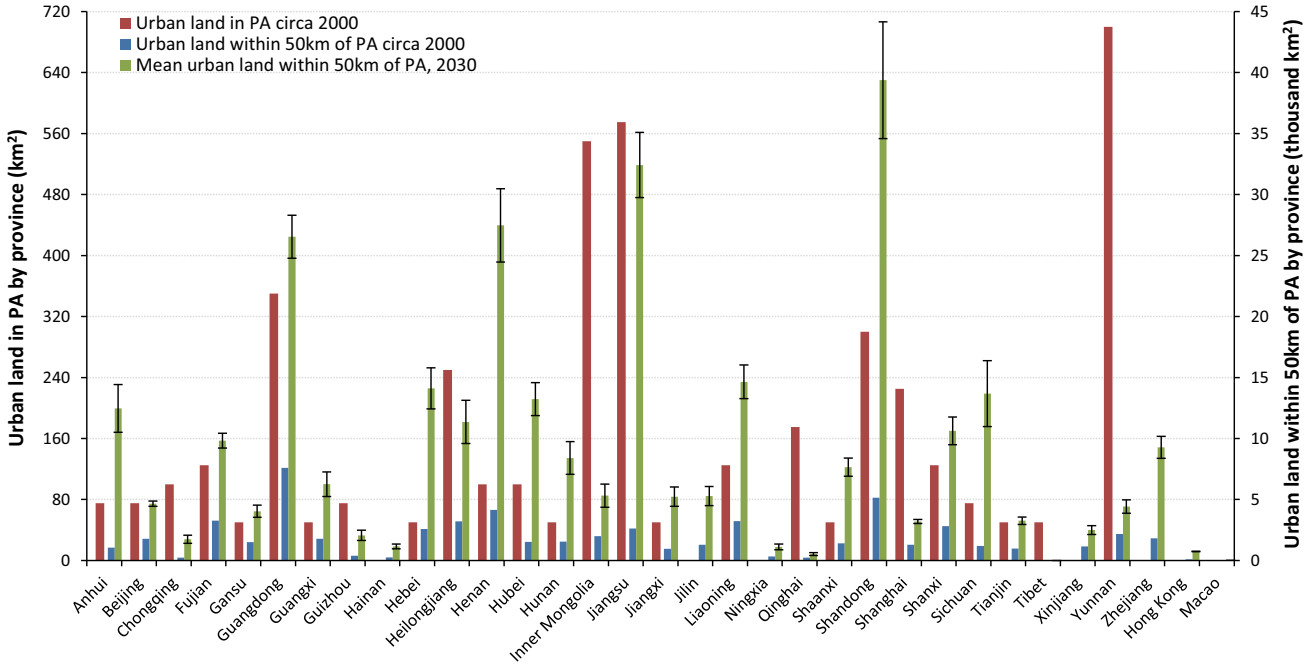


**Fig. 5** Urban land in PAs and within 50 km of PAs *circa* 2000 and as forecasted in 2030 by province. *Error bars* show one standard deviation

**Table 1** Total area of hotspots that fall within China's borders and forecasted change in urban land within them between 2000 and 2030

| Biodiversity hotspot | Area in China (km$^2$) | Urban in hotspots (km$^2$): average (SD) | | Percent increase in urban: average (SD) |
|---|---|---|---|---|
| | | Year 2000 | Year 2030 | |
| Himalaya | 181 625 | 0 | 0 (0) | 0 (0) |
| Indo-Burma | 350 025 | 9450 | 31 272 (2250) | 231 (24) |
| Mountains of Central Asia | 247 525 | 650 | 1556 (261) | 139 (40) |
| Mountains of Southwest China | 279 025 | 275 | 679 (179) | 147 (65) |
| Total | 1 058 200 | 10 375 | 33 507 (2587) | 223 (25) |

previous two decades. Indeed, Guangdong alone accounted for almost two-thirds of the total urban area in the biodiversity hotspots across China (Table 2).

Yunnan also had considerable urban land (about 600 km$^2$) in the Indo-Burma and Mountains of Southwest China hotspots; that is equal to about a fifth of the total urban land in the province (Fig. 2; Table 2). Similarly, Xinjiang in the northwest of the country contains the whole Chinese portion of the Mountains of Central Asia hotspot and had about one-fifth of its total urban land (600 km$^2$) within the hotspot.

## Forecasts of urban expansion near PAs and in biodiversity hotspots

We forecast that the amount of urban land within 50 km of the PAs will increase on average nearly 150 % by 2030 across the country (Fig. 3). By 2030, its urban land within 50 km of its PAs is expected to increase by 3.5–5.5 times, reaching to about 270 000–335 000 km$^2$. Within the country, most urban expansion near PAs is expected across the highly populated plains along the coast and the Yellow River. In particular, Shandong, Guangdong, Jiangsu—all coastal provinces—and Henan, a province on the fluvial plains of the Yellow River are forecasted to have the largest amounts of urban land within 50 km of their PAs in 2030 (Fig. 5). The largest percentage increases within 50 km of PAs by 2030 are, on the other hand, expected in three provinces along the Yangtze River. Two of these are also located in the east: rapidly developing Jiangsu Province, which also has the highest GDP per capita of all Chinese provinces, and the mostly flat and densely populated Anhui Province (Fig. 4b). The third province, Sichuan, is home to one of the few major industrial centers in Western China. Its capital Chengdu is one of the most important transportation and communication hubs in the country (Schneider et al. 2005).

**Table 2** Urban land and percentage of total urban land by province within biodiversity hotspots *circa* 2000 and as forecasted in 2030

| Province | Urban in hotspots ($km^2$): mean (SD) | | Percent change in urban: mean (SD) |
|---|---|---|---|
| | Year 2000 | Year 2030 | |
| Fujian | 125 | 277 (34) | 122 (27) |
| Guangdong | 6725 | 22 678 (1200) | 237 (18) |
| Guangxi | 1650 | 5555 (870) | 237 (53) |
| Hainan | 275 | 1183 (195) | 330 (71) |
| Hong Kong | 100 | 762 (17) | 662 (17) |
| Macao | 25 | 25 (0) | 0 (0) |
| Qinghai | 25 | 25 (0) | 0 (0) |
| Sichuan | 175 | 557 (173) | 218 (99) |
| Tibet | 25 | 27 (8) | 9 (31) |
| Xinjiang | 650 | 1556 (262) | 139 (40) |
| Yunnan | 600 | 862 (115) | 44 (19) |
| China | 10 375 | 33 507 (2587) | 223 (25) |

The most significant change by 2030 is that urban land in the Chinese portions of the Indo-Burma and the Mountains of Central Asia hotspots is expected to increase more than 200 % to over 30 000 $km^2$ (Table 1). The largest increases are forecasted in Guangdong and Guangxi provinces—both in the Indo-Burma hotspot. In the interior, Sichuan, which contains large areas of the Mountains of Southwest China hotspot is forecasted to have three times as much urban land within the hotspot by 2030 (Table 2).

In China, there are provinces such as Guangdong with substantial amounts of urban land both in the vicinity of PAs and in biodiversity hotspots (Fig. 5; Table 2). Several provinces, on the other hand, have no biodiversity hotspot, yet are forecasted to experience substantial amounts of urban expansion near the PAs. These include the coastal provinces Shandong, Jiangsu, and Liaoning that are all away from any of the four hotspots although considerable urban expansion is forecasted near their PAs (Fig. 5).

## DISCUSSION

### Balancing future urban growth and conservation in China

Our findings reveal the extent of urban land cover in relation to habitats important for biodiversity conservation in China at the turn of the twenty-first century. The spatial distribution of urban land across China in and near the PAs and in the biodiversity hotspots was already extensive *circa* 2000. We also show that the PA network, more extensive in the eastern and central parts of the country (Fig. 4a), will inevitably be encroached upon by future urban expansion. Existing PAs will face severe pressures of land change and urban expansion because unless specific actions are taken, significant amount of urban expansion is expected near the country's PAs. The forecasted expansion of urban land in the biodiversity hotspots as well as near the PAs vary widely among the provinces. Since there are fundamental differences between PAs and biodiversity hotspots as conservation tools (Brooks et al. 2006; Dudley 2008), whether a province is expected to experience urban expansion near a PA (e.g., Shandong) or in a biodiversity hotspot (e.g., Guangxi) or both (e.g., Guangdong) may require differentiated urbanization strategies to minimize the negative impacts on biodiversity. In particular, Guangdong Province was identified in a recent national assessment among those provinces that particularly require further funding for conservation given the richness of their biodiversity (Xu et al. 2008).

Yunnan Province may stand to lose the most, even though we forecast modest rates and amounts of urban expansion relative to the rest of the country (Fig. 2). The province has the richest biodiversity in all China, and it has about 10 % of the PA extent of the country (Yang et al. 2004)—in contrast, the province constitutes 4 % of China's land area. The extraction of various natural resources such as timber, road construction (Xu and Wilkes 2004), and mining activities have already increased in the province concurrent with economic development (Zhou and Grumbine 2011). These activities may continue to increase across the province together with further urban growth even though we forecast that urban expansion within the province will primarily be confined to the capital Kunming and its environs.

The large urban agglomerations of Chengdu in Sichuan Province and Ürümqi in Xinjiang Autonomous Region, while not located within any hotpots, are less than 20 km of the Mountains of Southwest China and Mountains of Central Asia hotspots, respectively. Land-use plans for these regions and the municipalities that comprise them could help direct new development away from these hotspots. For provinces that share the same biodiversity hotspots such as Yunnan and Sichuan (Fig. 4a), cooperation mechanisms among the local and regional land-use planning and conservation agencies would help protect transboundary resources (Shi et al. 2005). As the next section describes, however, there are numerous challenges standing in the way of effective land-use planning for conservation.

### The challenge for Chinese planning institutions

Formulating strategies to direct growth away from habitats critical for biodiversity conservation and to establish

regional cooperative land-use planning mechanisms require integrating ecological knowledge into urban growth strategies (Niemelä 1999). Formidable barriers currently stand in the way of achieving this kind of integration in China, however. The country's existing policy environment and incentives for local officials strongly favor rapid urban expansion over more careful and ecologically-minded urban planning. This bias stems from land and fiscal policy reforms introduced in the late 1980s and early 1990s. With the introduction of land markets in the 1980s, local governments have used land leasing, a process referred to as conveyance, to raise revenue; these land-related revenues became even more crucial to localities with fiscal reforms in the 1990s that allowed them to keep a greater share of this income rather than share it with higher levels of government (Peterson 2007). The result is a rush to convert new land to high-intensity urban uses, especially housing units to be sold for profit in China's new real estate market (Huang 2012).

New regulations were introduced in early 2000s for the central government to have more control over urban land development (Zhang et al. 2014). These include policies to increase the transparency of land markets and to recentralize land-management decisions. However, they did little to sufficiently change the existing economic, fiscal, and political incentives that motivate local governments to rely on land transfers as a revenue source and to bolster the standing of their officials (Lin and Ho 2005). In addition, local governments have access to enough capital, land, and labor to advance local development projects. Thus, the existing hierarchical governance structure sustains an institutional environment in which the local governments ultimately remain to be more influential than the central government in shaping urban development.

Should China's central government change the existing, over-arching incentive structure and policy framework, it could then enable its extensive planning bureaucracy—its various policies and guidelines and its community of professional planners, government agencies, and planning organizations—to move beyond its current role of enabling growth and environmental change to a more conservation-oriented and effective regulatory role (Abramson 2008). One component of the government bureaucracy that would be affected by such a change is the Ministry of Housing and Urban and Rural Development (MHURD), which oversees China's urban planning system and has the authority to enforce a national-level policy called the City and Town Planning Law (CTPL). The CTPL contains the basic requirements for local government units to guide their urban development with a series of plans that operate at various scales. One type of plan required by the CTPL is called the City and Town System Plan, which is typically formulated at the provincial scale. City and Town System Plans constitute a potential tool for provincial governments to think carefully about the spatial distribution of urban land within their jurisdictions and to implement measures to encourage growth away from more ecologically sensitive areas. However, much large-scale planning in China remains at present a pro forma exercise and lacks the teeth to regulate effectively the development decisions of lower level governments (Abramson 2008).

Below the provincial level, individual municipalities are required under the CTPL to guide urban development with urban comprehensive plans. These plans specify the amount of land that the city will occupy for current and future urban development, and local governments are required to have these plans approved by higher levels of government. Therefore, urban comprehensive plans represent another mechanism by which China could regulate urban growth to protect biodiversity hotspots and PAs. In practice, however, given the existing economic incentives for rapid development, these plans have been used as a tool for city governments to maximize the amount of land available to them for construction, and the approval process has not necessarily prevented new construction from being approved at the local level even while higher-level approval of plans is pending.

A second component of government bureaucracy that could play a greater role in safeguarding biodiversity and PAs against rampant urban development is the Ministry of Land and Resources (MLR) and its affiliated agencies throughout the government hierarchy. At the central government level, the MLR is concerned with maintaining China's food security and adequate supply of farmland, and it has sometimes exerted its authority to prohibit conversion of farmland to urban uses (Cartier 2001). The MLR also requires all cities to produce comprehensive land-use plans, which typically cover a broader spatial scope than the urban plans formulated in accordance with the CTPL under MHURD. According to the CTPL, a city's urban plan must conform to and operate within the framework of the comprehensive land-use plan. In practice, however, urban plans across China have been made and revised before the comprehensive land-use plan is finished, thereby diminishing the MLR's planning efforts as an effective regulatory mechanism. Furthermore, it has been noted that officials within China's land administration system, at the local level, have interests in promoting, rather than constraining, new urban construction (Wong and Zhao 1999).

From this examination of China's institutions for land-use and urban planning, it is clear that policies and personnel are in place that could facilitate the integration of natural resource protection into the planning process, but the existing incentives and institutional arrangements between the central and local governments prevent this kind of integration from taking place. If the trends of the

past three decades continue, urban expansion dynamics in China will primarily be dominated by economic forces, which include the role played by land transactions as a source of income for the local governments.

China's newly-unveiled urbanization plan acknowledges that municipal governments' over-reliance on land leasing as a source of revenue has resulted in inefficient urban development and presents a challenge for transitioning to an "ecological civilization" (China State Council 2014). In spite of this recognition from the central government as well as the professional opinions and aspirations that individual planners and planning officials might have that would favor more ecologically-minded urban planning, it remains uncertain the extent to which China's government will implement reforms that allow planning to move beyond its current, growth-enabling role.

### Uncertainties in urban expansion forecasts

Future urban expansion patterns in China bear significant uncertainty due to potential changes in the social, economic, and institutional factors driving urban land development in the country. Through our probabilistic framework, our forecasts partly account for such uncertainties. For example, with the further relaxation of the one-child policy in the country (Liu 2010; Gross 2014), urban expansion may speed up. Another demographic factor is the decrease in household size (Liu et al. 2003). The resulting increase in the number of households often inflates the demand for residential land. On the other hand, the slowdown in the Chinese economy, if it persists, will mean that the actual urban expansion will be toward the lower end of the forecasted distribution. For example, there is a possibility that the Chinese economy may be badly crippled in case of defaults by local governments on their high levels of debt—the legacy of the investment booms over the past decades (Tsui 2011).

Significant changes in national urbanization policies such as further reforms on land management and fiscal arrangements across the government hierarchy may also alter the spatial pattern of urban land expansion across the country. In particular, our probabilistic forecasts point to much less urban expansion in western China compared to the eastern provinces. However, this may change as a result of the ongoing commitment of the central government to direct urbanization toward western provinces and as eastern provinces further lose their attractiveness due to increasing costs of living. There are several other factors that may significantly influence regional and local urban land expansion trends including foreign investment (Seto et al. 2011). Foreign investment on real estate, initially concentrated along the coastal urban centers, have over time spread through large cities in central and western China fueling their growth (He and Zhu 2010). To the extent the urban transformation seen in the east of the country will be repeated in the western regions, the impacts on biodiversity may be more far-reaching than we forecast here.

Finally, we assume there will be no urban expansion within the boundaries of the PAs. This is a conservative assumption that helps us highlight the challenges the PAs face due to urban expansion in their vicinity even though no urban expansion is permitted within their boundaries. An alternative approach would be assuming different levels of urban expansion within the PA boundaries, perhaps as a function of the PA status (e.g., IUCN designations from I to VI). However, in the absence of consistent information regarding urban expansion within the boundaries of different PAs across the country, we decided not to follow this approach. If such information is forthcoming, it would be worthwhile to incorporate this component to test different scenarios regarding the effectiveness of enforcement in preventing urban expansion within PA boundaries.

## CONCLUSION

China is facing increasing pressure to address its mounting environmental problems that have been brought about by its economic growth and urbanization over the past 35 years (Grumbine and Xu 2013). As urbanization progresses across the country, large areas within the biodiversity hotspots and more land near nature reserves are likely to be affected by urban expansion. Urban expansion is expected to concentrate along the coast and lower floodplains of the Yangtze River and the Yellow River increasing the pressure on the PA network across the east of the country. The varying pace of urban expansion as well as differences in biodiversity across the provinces will mean that the need for integrating biodiversity conservation into urbanization strategies will be more pressing in certain provinces such as Yunnan and Guangdong. Overall, there is an urgent need to reform the institutional and regulatory structures that give rise to rapid urban expansion in the country.

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