



Analyzing the outcomes of China's ecological compensation scheme for development-related biodiversity loss

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Abstract

Over the past three decades, China's government has implemented many projects under its ecological compensation policy, including paying compensation fees for habitat creation to redress natural habitat losses caused by development. However, a critical evaluation of both the policy design and its ecological outcomes, has not previously been carried out. We assemble diverse data sources to provide the first evaluation of China's eco-compensation policy and practice, identifying several challenges. In policy, the pricing of forest restoration fees is insufficient in several provinces, and there is no requirement for use of biodiversity metrics or for ecological equivalence of compensation and losses. In practice, only 23% of a sample of 31 developments applied quantitative biodiversity metrics, and fewer than 1% of China's local governments have disclosed information regarding compensation implementation. Thus, to improve the validity of its compensation policy and practice to better secure biodiversity, China may need to embrace higher compensation standards, having first prevented ecological losses where possible. Equally important, China may also need to improve compensation governance for data tracking and conservation effectiveness monitoring.

KEYWORDS

biodiversity offsetting, China, ecological compensation, environmental impact assessment, mitigation hierarchy, net gain, no net loss

1 | INTRODUCTION

Human overexploitation of land and natural resources has been identified as among the most substantial anthropogenic drivers of biodiversity loss (Maxwell et al., 2016; Newbold et al., 2016). As humanity endeavors to remain within a safe operating space defined by planetary boundaries (Díaz et al., 2019; Rockström et al., 2009), compensatory conservation has become a widely employed approach

to reconciling potential losses caused by economic development with goals for nature (Damien, Backstrom, & Gordon, 2021; Maron et al., 2018; Simmonds et al., 2022). Compensatory actions are the last steps of the biodiversity “mitigation hierarchy,” which should be implemented after the preventative steps of avoidance and minimization (Arlidge et al., 2018; Gardner et al., 2013; McKenney & Kiesecker, 2010). Over 100 countries globally have incorporated, or are incorporating, compensatory actions to

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mitigate biodiversity impacts into their national environmental policies, according to the Global Inventory on Biodiversity Offset Policies database (IUCN, 2019). Compensatory actions mitigate and compensate for negative impacts on biodiversity associated with a given development project by enhancing biodiversity elsewhere, typically seeking an overall outcome of no net loss (NNL), and preferably a net gain (NG), in biodiversity. How compensatory actions and NNL/NG goals are institutionalized and implemented to address development impacts varies between countries (Maron et al., 2018). Yet there has been little quantitative work exploring China's ecological compensation policy and its implementation in China.

Filling this knowledge gap is important because nowhere is the potential trade-off between economic development objectives and biodiversity protection more extreme than in China. One of the world's megabiodiverse countries, China's fast urbanization and industrialization after market reforms starting in 1978 has fuelled an approximately thirtyfold increase in GDP per capita and lifted 850 million people out of poverty (World Bank, 2022), but it has also brought tremendous costs for the natural environment. Developments have destroyed a great number of natural habitats, including forests, grasslands, and wetlands, resulting in massive environmental losses: For instance, within China's Pearl River Delta, 1518 km² or 26% of the natural habitat and 760 km² or

42% of the local wetlands were lost from 1992 to 2012 (He et al., 2014). Over the last decade alone, China has undergone the most rapid infrastructure expansion observed in human history—it has been estimated that China consumed more concrete in 2011–2013 than the USA did in the entire 20th century (Smil, 2016).

To reverse ecosystem losses, in the late 1990s and early 2000s China's government gradually launched a comprehensive national eco-compensation strategy with a number of subsidiary policies and programs, with the primary principle of internalizing both positive and negative environmental externalities of human activities (Shang et al., 2018). The strategy has supported a steady increase in habitat area in China; for example, China's forest area (% of land area) has increased from 18.9% to 23.4%, according to the World Bank. Based on this primary principle, in a broad sense China's eco-compensation strategy encompasses both reactive and proactive measures for redressing environmental losses caused by economic activities, both legal and illegal, which have both taken place in the past and are currently ongoing (Table 1). Understanding the policy landscape in China is complicated by different nuances in the usage of the word “compensation”: but the first type of compensation measure in Table 1 is close to the “compensation” or “offsetting” tools applied elsewhere, such as the “biodiversity offset” of Australia, “compensatory mitigation” of the United States, and “conservation offset” of Canada.

TABLE 1 The multiple meanings of “eco-compensation” in China's policy mix. In this chapter we focus on eco-compensation measure type 1 (compensation for contemporary development impacts).

Eco-compensation measure	Description	Externality	Liability	Example
1. Compensation for contemporary development impacts	Reactive, disincentive-based compensation for legal, contemporary, attributable impacts	Negative	Polluters/developers pay for public interest	Forest vegetation restoration fee (IUCN, 2019; Madsen et al., 2010; OECD, 2016)
2. Compensation for previous development impacts	Proactive compensation for both (previously) legal or illegal, past, indirect, and diffuse impacts	Negative	Governments pay for public interest	Yangtze river protection and restoration action (World Bank, 2022)
3. Payments for ecosystem services	Proactive, incentive-based compensation for previously permitted, long-lasting impacts	Positive	Governments pay, and providers get	Grain for Green (also known as Conversion of Cropland to Forest Program) (Liu, 2002; Song et al., 2021; World Bank, 2022)
4. Compensation for illegal use of natural resources	Reactive compensation for illegal, contemporary, attributable impacts	Negative	Offenders pay for public interest	Compensation fees or rehabilitation projects for illegal activities such as illegal fishing and illegal land reclamation (Kong et al., 2021)

This type of measure is the focus of this study, which we will refer to as “compensation” from here on.

To implement compensation to counterbalance development impacts, China has designed and established a compensatory mechanism, including the forestry vegetation restoration fee (FVRF), grassland vegetation restoration fee (GVRF), and wetland restoration fee (WRF). FVRF was launched through China's first Forestry Law in 1998. It was the earliest developed and, to date, the most widely applied compensatory instrument in China. Given that it incorporates a legal commitment to realizing NNL of forest cover alongside development activities, FVRF is also internationally regarded as China's principal NNL instrument (IUCN, 2019; Madsen et al., 2010; OECD, 2016). The reason that FVRF has been broadly implemented is not just because of its early adoption, but also as a result of China's prioritization of forest protection and afforestation as a primary focus for the provision of regulating services and promotion of sustainability on land. Intensive afforestation and forest restoration measures have been launched since the mega-floods in 1998 exacerbated by soil erosion and siltation, which swept through many of the country's major rivers, including the Yangtze, Songhua, Nen, Min, and Pearl rivers (Du et al., 2019; Lang, 2002; Zhang & Wen, 2008). Moreover, afforestation and forest restoration programs have contributed to reducing China's long-standing issues with regional sand and dust storms in the dry north and rocky south arising from denudation and desertification (Bryan et al., 2018; Wang et al., 2010; World Bank, 2022).

Despite the widespread application of China's compensatory mechanism (the first approach in Table 1), there has been little to no research into the outcomes and efficacy of these compensation policies. Previous studies published in Chinese focused on compensation for past development impacts, incurred before environmental issues were more seriously addressed by government (i.e., the second type of compensation shown in Table 1), especially in protected areas or ecosystems of high conservation priority (Liu et al., 2022). Although massive developments and associated compensatory activities are currently occurring in China's urban and semi-natural rural areas, their scale and mechanisms have not yet been comprehensively explored. Additionally, discussions around China's compensatory mechanisms are topical; in 2021 China's central government has made commitments to increasingly prioritize biodiversity conservation in future development, to enhance its ecological compensation method for better redressing the consequences of removing natural habitats, and to seek better approaches to assessing the biodiversity impacts of development activities, such as construction and mining (State Council, 2021a & 2021b).

We address three research questions in this study:

- How is compensation conceptualized in China's policy?
- How does compensation work in practice in China?
- Can China learn from international best practice in compensation to enhance its compensation approach, better securing its national biodiversity?

Investigating China's compensation policy and practice can help elucidate whether China's long-standing compensation approach supports or clashes with China's other or more recently set biodiversity goals and commitments. For example, China has an overall conservation goal of “*maintaining biodiversity*,” as indicated in its Forestry, Grassland, and Wetland Protection Laws (Ministry of Ecology and Environment, 2021a, 2021b, 2022). The Forestry Law also requires the forest compensation fees collected to provide sufficient revenues for developing the same area of forest elsewhere as has been lost. However, how China's compensation fee approach works has not yet been studied. Additionally, although compensation has been implemented in many countries, including the United States, Australia, Germany, and France, in each case, the ecological outcomes of previous compensation programs have been mixed (Bull & Strange, 2018; Zu Ermgassen et al., 2019). Given this lack of consistent progress, it is crucial to evaluate the outcomes of compensation in different contexts. As major global financial flows and policy efforts are currently being directed towards compensatory actions and biodiversity restoration, evidence from China can contribute toward developing a general understanding of whether and when compensation can be effective. To address the proposed research questions, we review the compensation system being used in China and link it with the desired conservation goals proposed in China's legislation—we then discuss the approach China is taking in the context of the fundamental ecological principles required for effective compensation.

The remainder of this study is constructed as follows. The next section discusses the materials and methods used for evaluation. Then, we present our results to answer the three proposed questions in order: (a) how China conceptualizes ecological compensation, (b) how China practices ecological compensation, and (c) how China can improve based on what we found in (a) and (b). Finally, we conclude with a summary of policy suggestions and recommendations for future work.

2 | MATERIALS AND METHODS

Instead of quantifying the conservation effectiveness of compensation, this study takes a process-based approach

to analyzing the outcomes of China's compensation. Because the concept of compensation is interpreted heterogeneously in different contexts around the world (Damians, Porter, & Gordon, 2021), before carrying out an assessment of its outcomes, we first conceptualize compensation in China and review previous compensation literature, in order to develop a set of indicators to assess compensation in a way that is meaningful in China's context.

(1) *Review of policy, regulations and government documents relevant to China's compensation mechanism.* Due to the lack of public information about China's compensatory mechanism, we collected information from different sources to provide the first overview of how the compensatory mechanism works in China. We reviewed two sets of government documentation at both central and local levels. First to understand the mechanisms behind how China's compensation policies function, we reviewed all relevant policy, regulation publications and other relevant government reports provided by the central government, including *Forest Vegetation Restoration Fee Levy, Use and Management Provisional Measures*, and *Guiding Opinions on Formulating Conditions for Restoration of Vegetation and Forestry Production*, as well as relevant policy papers published by China's 31 provincial-level governments, through searching on the 31 provincial-level governments' official websites using the keyword of forest vegetation restoration fee (*senlin zhibei huifufei*).

(2) *Sampling of developers' environmental impact assessment (EIA) reports that recorded developments' biodiversity impacts.* We identified the biodiversity indicators implemented in Chinese compensation plans using developers' EIA reports. To our knowledge, there is currently no official database that records all EIA reports in China. Some EIAs have been collected in some voluntary document-sharing databases, such as Doc88 (*Daokebaba*) (<https://www.doc88.com>). However, the database is not systematic; it provides a sample of reports that were uploaded by database users. We used the keyword of "environmental impact assessment reports" (*huanjing yingxiang pingjia baogao*), to screen complete EIA reports on this database. Thirty-one economic development projects were selected from a total of 500 results; we first removed all incomplete reports (e.g., documents that only present half or one module of the entire assessment) and then manually selected projects whose titles contained keywords regarding infrastructure or real estate development (e.g., housing, hospital, road, railway) to present the developments that are most likely to be associated with ecological impacts.

The number of development projects we collected may not generate a full picture of EIA in China, given

the massive scale of China's development (Smil, 2016). In order to make our results as generalizable as possible, we sampled projects that covered different development types and geographical regions: out of China's 31 provincial-level administrative regions, we included a total of 31 development projects across 15 regions with 13 provinces and 2 municipalities, which covered 6 types of developments (from housing to bridge construction, see Section 4.1).

(3) *Understanding China's compensation system through exploring local government disclosures.* Some EIA reports also contain some compensation practices planned voluntarily by developers to improve the likelihood of the projects being permitted by the planning authorities, and possibly to reduce the cost of restoration fees paid to the government (or increase the size of their rebate). This information is also shown in Table S1. Yet, most of China's development and compensation practices are carried out independently: compensation practices are mostly completed by the forestry and environmental authorities using the restoration fees they have collected. We thus searched Baidu, the biggest Chinese search engine, with the keyword of "forest vegetation restoration fee" (*senlin zhibei huifufei*), "grassland vegetation restoration fee" (*caoyuan zhibei huifufei*) and the many translations of "expense" and "spending" (including *huafei*, *zhichu*, and *shiyong*) and the domain name of "gov.cn." The search was performed between November 2021 and January 2022. We reviewed a total of 1315 pages and identified all government pages that documented government spending financed through the restoration fee and compensation implementation practices. We screened out the pages simply recording the charging requirements and general information about collection and transfer of the fee and ultimately identified 10 local governments which had released the required information.

(4) *Evaluating China's forest vegetation restoration fee.* We also aimed to see if the prices paid by a developer to compensate an area of natural habitat loss induced by its development project enable the recreation of the same area of natural habitat elsewhere. This study investigates the price levels of China's most widely applied compensation fee, the FVRF (Gong et al., 2014; Jeffrey & Qi, 2012; Zhen & Zhang, 2011), to see if the prices used can actually cover the total costs needed to enable>NNL of forest areas in the same region. We thus calculated the unit cost of forest investment from 2016 to 2018 using different regions' annual total investments in forests, and the yearly increase of afforestation areas in each region, collected from China's National Statistics Data from 2017 to 2019 (<http://www.stats.gov.cn>). The investments in forest development, as claimed by the government, involve

investments in degraded forest restoration and compensation, forestry planning and development, forestry loss prevention, and other forestry management activities. The yearly increase in afforestation area includes the increases from all the means used to develop forests, including both creating new forests and restoring degraded forests. The data published from 2020 are no longer applicable to the analysis because the statistical accounts changed, with the government spending in grassland development merged with its spending in forest development. The data on gross regional product per capita across China from 2016 to 2018 were collected from the nation data page of National Bureau of Statistics of China (<https://data.stats.gov.cn>).

The measurement of total investment in forest management reported by the government is used to estimate the sum of all the costs spent, including both explicit reforestation costs and implicit transaction costs (e.g., misappropriation), to deliver reforestation. The details of how such investments by China's government have been spent in different regions are usually impenetrable or unavailable, and China's forestation funds are in practice allowed to be used to deliver a wide range of natural capital benefits for people's well-being in addition to habitat compensation. Here, we aim to reveal how much input (i.e., total spending on forest development) is required to be invested to realize the expected nature-related output (i.e., NNL of forest area) without unpacking the black box of government spending, and to compare the unit costs with the current FVRF levels in different regions. As information about the areas of every

type of forest land delivered each year is unavailable, a sensitivity analysis is performed to consider the best, worse, and average situations. The best situation assumes all the forest development investment was used for developing the type of forest land with the highest FVRF prices (i.e., arbour forest land, defined in Table 2). The worse situation assumes all the investment went to develop the type with the cheapest FVRF (i.e., young afforested land). The average scenario supposes all types of forest land—arbour forest land, bamboo forest land, nursery land, shrub forest land, sparse forest land, and young afforested land—are developed equally by area.

This quantitative analysis assumes (i) China's statistical body correctly reports its investments and forest area increases, and (ii) government spending is the primary driver of afforestation, due to China's top-down system within which land and forest are mostly treated as public property and managed by the government. The analysis is limited by uncertainty in China's statistical manuals, such as the lack of description of the method used to collect and compute data, as well as linguistic uncertainty. For example, there are no clear definitions of terms such as forestry loss prevention and forestry management practices. Together with other unclear definitions (e.g., "important" wetlands) in China's policy papers, standards, and laws and regulations relevant to its compensation approach, it is not possible to analyze its outcomes with full confidence. We endeavor to make a rigorous assessment, after first understanding China's context as well as possible via cross-referencing documents, to reduce any inaccuracies as far as possible.

TABLE 2 Types of forest lands and National Standard Fees, as set in 2015.

Forest land	Description	Standard fees (CNY/m ²) ^a
Arbour forest land	Forest land composed of arbour species (i.e., trees that have a distinct trunk, with tree height >5 m and diameter at breast height >5 cm at maturity), with a crown density ≥ 20%; or a crown density < 20% but retention rate ≥ 80% with steadily growing young trees in planted stands	No less than 10
Bamboo forest land	Forest land composed of bamboos with a minimum diameter at breast height of 2 cm	No less than 10
Nursery land	Land permanently used for cultivating tree seedlings and saplings	No less than 10
Shrub forest land	Land composed of shrubs and/or bushes with a canopy cover more than 30%	No less than 6
Sparse forest land	Arbour forest land, but with a canopy cover of 10%–19%.	No less than 6
Young afforested land	Afforestation land, with no closed canopy, but the actual number of planted trees is no less than 85% of the planned number	No less than 6
<i>Suitable land for forest^b</i>	<i>Land suitable for forestry development.</i>	<i>No less than 3</i>

^aCNY (Chinese yuan renminbi) is official currency of People's Republic of China; 1 CNY = 0.14 USD.

^bThis by China's definition includes cut-over lands, slashed and burned lands, glades and other barren hills and wastelands unsuitable for crops but suitable for trees. This type of land is not considered as a forest land type in this article.

3 | CONCEPTUALIZATION OF COMPENSATION IN CHINESE POLICY

Since China's first Forestry Law, published in 1998 (followed by the Grassland Law in 2002 and Wetland Protection Law in 2021), China's central government requires compensation to be implemented by development projects that remove forest, grassland, or wetland habitats (Madsen et al., 2010; Ministry of Ecology and Environment, 2021a, 2021b, 2022). Correspondingly, three mandatory compensatory fees are used to address the ecological externalities of developments: FVRF, GVRF, and WRF. According to China's Forestry, Grassland, and Wetland Protection Laws, the three fees implicitly have an NNL-like goal; to “maintain biodiversity (*weihu shengwu duoyangxing*)” (Ministry of Ecology and Environment, 2021a, 2021b, 2022).

Given China's prioritization of forest habitat (World Bank, 2022; Xi et al., 2022), FVRF has become a widely applied measure across China. By contrast, to date, GVRF has only been used in some regions while WRF is still in its infancy. FVRF uses an NNL goal—NNL in the area of forest cover undifferentiated by forest type (Madsen et al., 2010; Ministry of Ecology and Environment, 2021a)—while WRF aims to compensate for the loss of “important wetlands” with the same quantities and qualities elsewhere (Ministry of Ecology and Environment, 2022), though which wetlands are considered important is not yet clearly defined. In contrast, GVRF to date does not have any explicit NNL target (Ministry of Ecology and Environment, 2021b).

China's government to date has not provided a clear overview of how the compensatory mechanism works. Therefore, here we summarize the procedure based on a review of policy papers published by China's national and local governments and some case studies across China (Figure 1). After a developer has conducted an EIA and has been granted consent to construct a development scheme by the government, the developer must pay restoration fees to the state. Unlike the compensatory schemes of the United States and Australia, developers in China are not required to negotiate prices with compensation providers, and prices paid to the government are not calculated on a case-by-case basis unless they plan to enact compensation by themselves. For instance, the prices applied in FVRF are set via a unified approach jointly by the China's Ministry of Finance and National Forestry and Grassland Administration. The prices are estimated to cover the total costs required to enable full compensation for the lost area of habitat cover in place, disregarding the quality of that habitat or its ecological functional role or species. For example, in terms of forest

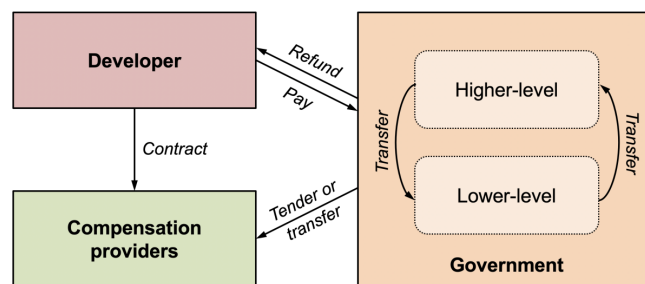


FIGURE 1 Procedure for China's compensatory approach.

(i) A developer calculates the total restoration fee based on the area of each habitat type and makes a payment to the government. As different habitats can be managed by different levels of government, the developer pays the level(s) of government (i.e., forestry and grassland office) that manages the relevant habitat(s). (ii) The collected fees may be transferred within the government, and is finally transferred to the local (i.e., county- or district-level) Treasury after a certain period (e.g., a quarter or half-year). (iii) If the developer eventually clears less habitat area than they first predicted, or restores some habitat area (e.g., by contracting a compensation provider), the government needs to refund the corresponding part of the fee. Once the local government comes up with spending plans and negotiates contracts with providers for sourcing young trees and for transplantation to create natural habitat(s) and/or restore existing natural habitat(s), the money is then transferred to the corresponding office to make the necessary payments. This money can also be transferred from the Treasury to other governmental bodies for other natural resource management activities such as forestry planning and fire prevention.

compensation, the estimation of FVRF is based upon the sum of costs of: (i) ecological survey, design and planning for forest cover regeneration, (ii) afforestation or reforestation, and (iii) forest management and monitoring. The two central government bodies published their first compensation prices in 2003 and an update in 2015 with all price levels increased (Ministry of Finance, 2015). As the GVRF and WRF have not yet been as widely applied nationwide as FVRF with clear price levels defined, this study evaluates China's compensation fee approach with a focus of FVRF.

In contrast with compensation approaches employed, for example, in the United States, Australia, Germany, and France, China's compensation policy is underlain by a “low-replaceability” principle (Koh et al., 2019), that is, they do not have to be “like for like.” According to China's National Forestry and Grassland Administration's policy paper and the national standard (GB/T 15776–2016) *Afforestation Technical Regulations*, species used in compensation projects should ensure the restored forest is long-lasting and resilient to extreme conditions in the area, but ecological equivalence is not required. The national standard *Afforestation Technical Regulations*

provides a recommended list of species from which compensation practitioners can choose to develop afforestation or reforestation projects.

It is hard to precisely define “forest” (Sasaki & Putz, 2009), and different countries and organizations do so differently. China's government defines “forest” in multiple ways based on regional context. Table 2 demonstrates China's typologies of forest land as used in the FVRF instrument, and the standard price levels that developers need to follow for occupying each type of forest land (Ministry of Finance, 2015). Within the top-down governance system, after the central state releases the goals, principles, and minimum requirements, lower-level governments have the autonomy to make adjustments based on their local situation. In turn, China's different provincial-level governments (i.e., governments of provinces and direct-administered municipalities) have the autonomy to increase the restoration price levels set by the central state, after considering the total costs of carrying out the compensatory actions in their regions.

3.1 | An evaluation of China's forest vegetation restoration fee

Figure 2 presents an overview of the prices each provincial-level government put on forest vegetation restoration, as of 2015. Most (74%) of China's provincial-level governments set price levels consistent with the

minimum price levels released by the central bodies, while Chongqing sets the highest prices on forest land compensation on average, at CNY 16/m². We then calculated the total costs of forest land development per square meter in China's 31 province-level administrative units using national statistics. Figure 3 further presents the ratio of the costs of forest land development to forest vegetation restoration prices from 2016 to 2018 across China; a ratio >1 means the cost of forest compensation is likely to be higher in practice than the fee charged to developers. We found that higher price levels enable sufficient coverage of the costs required for forest development in many regions, such as Chongqing, Guangdong, and Fujian, but not in other some provinces, such as Heilongjiang and Zhejiang. In particular, the costs of implementing forest compensation in some economically developed regions such as Beijing and Shanghai are much higher than in other places (Figures 4, S1), while the prices set in these places are too low to cover these costs.

4 | DELIVERY OF COMPENSATION IN PRACTICE

4.1 | Impact assessment and compensation on the development side

In practice—as is common for good practice biodiversity impact mitigation globally—development projects in

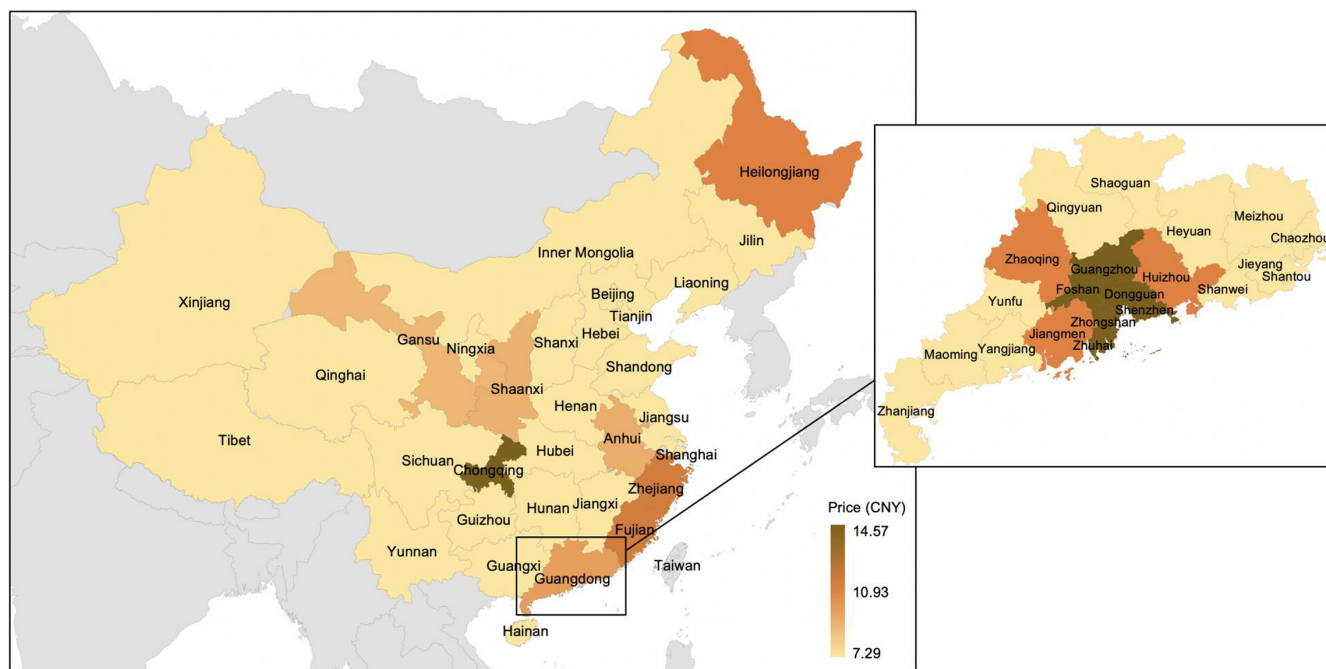


FIGURE 2 An overview of FVRF in China's 31 administrative divisions, as set in 2015. Mean of the seven price levels of FVRF applied in each provincial-level administrative region in China, calculated based on 31 regional policy papers; most provincial-level governments set the fees for all the sub-regions under their command, except that Guangdong Province set more detailed price levels for its sub-regions.

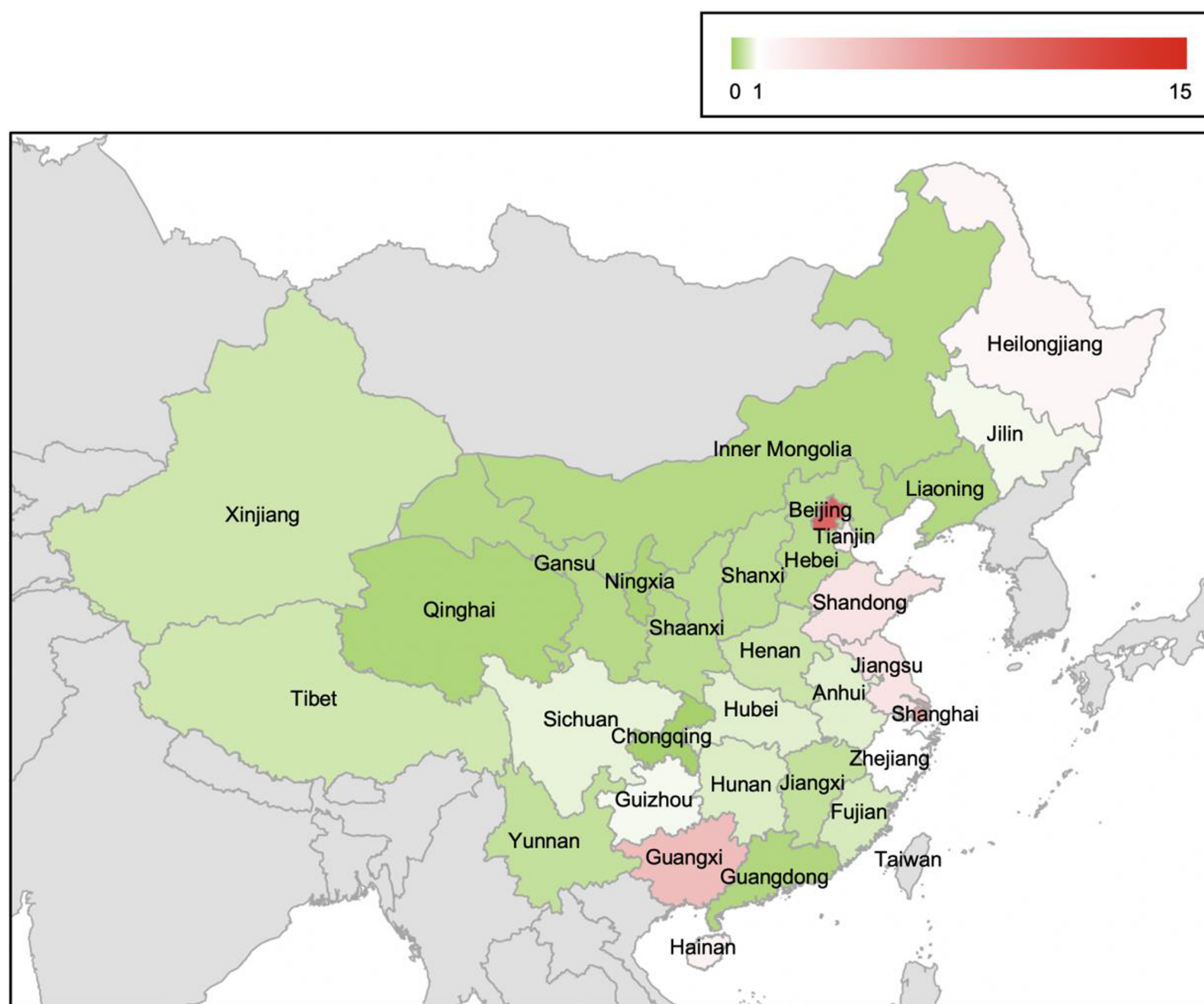


FIGURE 3 Cost-price ratios for Forest Development in China's 31 administrative divisions. The ratio of the total provincial government spending on forest development in each region to the price levels applied in China's FRVF in 2018 under the average-case scenario. The full result of a sensitivity analysis considering best, average, and worst-case scenarios is presented in Figure S2. The current price levels renewed in 2015 were less than the cost of compensation—which includes, if any, government corruption and misappropriation—in some regions including Beijing, Shanghai, Guangxi, Jiangsu, Shandong, Tianjin, and Heilongjiang. Suitable lands for forests (Table 2) are not considered in this analysis.

China are legally required to first identify and prevent development impacts on irreplaceable ecological components, following such regulations as the list of endangered and protected species of China and the “no-go” areas where development impacts are not permitted as determined by China's ecological redline policy (Bai et al., 2018; Jiang et al., 2019; Xinhua, 2017). The red lines identify areas that provide key ecological functions as well as ecologically sensitive and fragile areas. Developers can design compensation schemes in their EIA reports in order to gain governmental consent for their projects. The 31 development projects we sampled consist of 11 housing developments, 8 road constructions,

7 hospital buildings, 2 railway infrastructures, 1 school development, 1 bridge project, and 1 dam construction. All the projects have been permitted by the local authorities, though the Jiasajiang Level 1 Hydropower Station project has now been postponed due to a public lawsuit.

As shown in Figure 5, most (77%) of the cases studied did not employ any quantitative biodiversity indicator, as this is not a requirement for developers. In 45% of cases, the report describes “low levels of biodiversity on the development site” or “no protected or endangered animals or plants have been found,” with the EIAs concluding with statements such as “biodiversity (or the natural environment) has not been affected,” or “the influence on

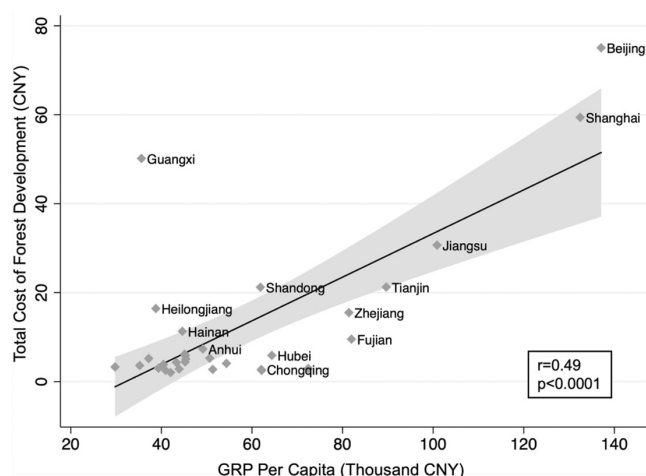


FIGURE 4 Relationship between total cost of forest development and GRP per capita in China. Three-year mean of total cost of forest development and GRP per capita from 2016 to 2018 in each provincial-level administrative region (mean: black line; 95% confidence interval: gray shaded area). In general, developing a given amount of forest is more expensive in economically more developed areas (e.g., Beijing).

biodiversity (or the natural environment) is negligible.” 32% of the EIA reports listed the names of affected family, genus, or species only; for example, the Chinese sumac (*Rhus chinensis*), the Chinese parasol tree (*Firmiana simplex*), magpies (*Pica pica*), or sparrows (*Passer montanus*). 10% of them incorporated an additional quantitative indicator of biomass or habitat area loss, while 13% carried out a more detailed assessment. For instance, the EIA report for Jiasajiang Level 1 Hydro-power Station applied biodiversity indicators including forest patch indices, habitat area, primary productivity, biomass loss, species traits, and species abundance. In EIAs which reported no impacts to important species or habitats (87% of cases), there was a clear trend towards using less complex biodiversity indicators.

Developer-led compensation practices tended to mix habitat-level activities with more elaborate landscape-level practices. Among all our sampled EIAs, 71% planned to carry out tree planting or urban greening projects, in order to “to some extent redress development impact” by restoring a certain area of natural habitat.

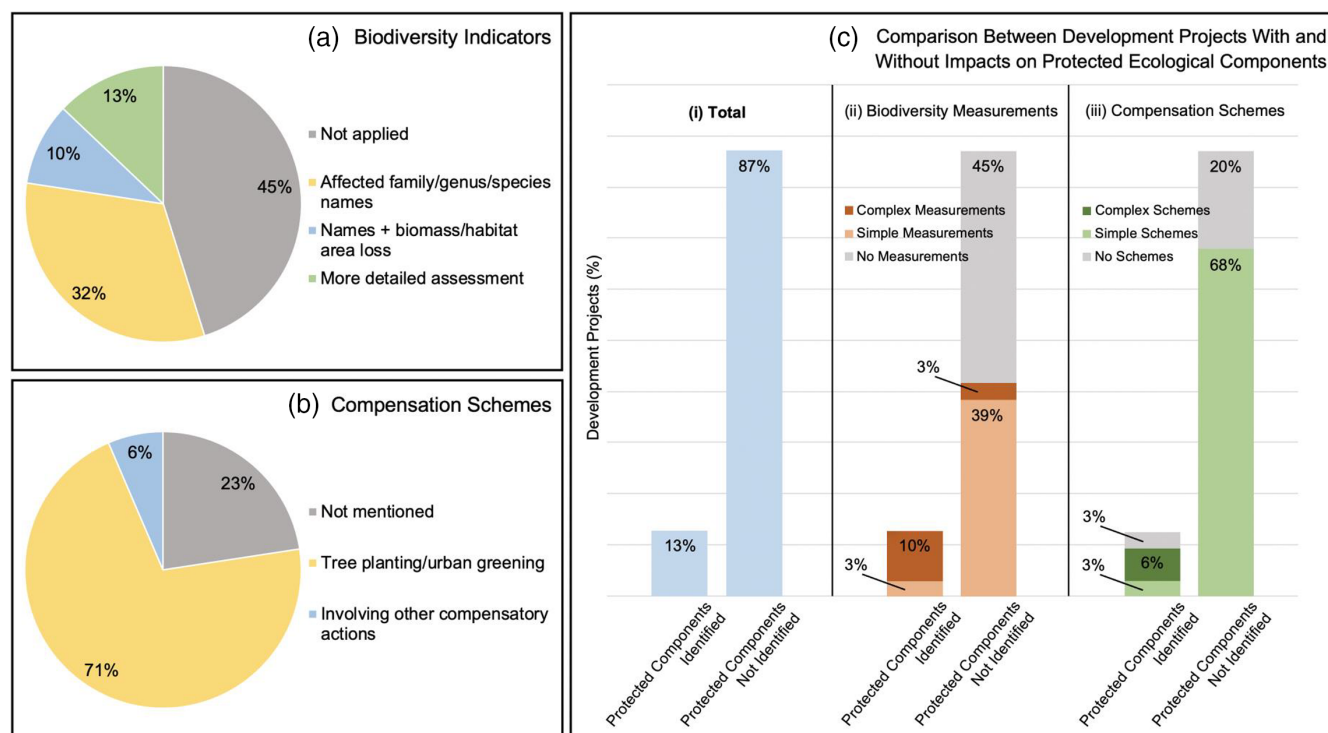


FIGURE 5 Characteristics of sampled EIA reports. Panel (a) demonstrates how developers characterize biodiversity. Panel (b) shows what types of compensatory actions are planned. Section (c) shows differences between EIA reports that (i) identify some (13%) or no impacts on protected species or habitats (87%), (ii) methods used for biodiversity measurement, and (iii) types of compensatory schemes. If impacts on protected ecological elements are not identified, EIAs tend to employ less detailed biodiversity measurements and come up with less complicated plans for compensations. “Simple measurements” means recording names of affected family/genus/species with or without an indication of the area of biomass/habitat lost. “Complex measurements” means an assessment that includes more detailed indicators, such as species abundance. “Simple schemes” include compensations that only deliver tree planting or urban greening. “Complex schemes” include schemes including other compensatory actions (e.g., fish ladders).

They are incentivized to replant vegetation and restore habitats on their own to reduce the risks of developments being rejected as well as to reduce the financial costs of restoration fees paid to the government. Six percent of all EIAs planned to conduct more detailed compensatory actions. For example, the 353 Provincial Highway (Yangzhou East Section) Project intended to (i) restore onsite grassland using medick (*Medicago*) and white clover (*Trifolium repens*), (ii) restore old and develop new fish ponds, and (iii) develop an offsite 1035.5- μ (\sim 69 hectare) tree planting project. In our sample of EIAs, we only identified the implementation of more complex compensation practices in projects which had identified an impact on protected ecological elements (e.g., ecosystems, habitats, or species). The one assessment that reported protected ecological elements but did not apply biodiversity indicators or design compensation actions was an EIA identifying impacts on one of China's protected bird species, magpies (*Pica pica*). The report concluded there would be no effect on the species, assuming that they would be capable of finding new habitats by themselves. In fact, all the EIA reports that identified impacts on birds and reptiles assumed their unrestricted ability to move elsewhere, with no critical interrogation of this assumption.

4.2 | Impact compensation delivered by local governments

Out of 2844 county-level governments, we found a total of 10 local governments that had disclosed information on their compensatory activities (Table 3). For example, Table 4 details the specific compensation land-management practices reported by the Forestry Bureau of Longhui County in 2020. The restoration fees by law should be spent on development or renewal of natural habitats. In China's compensation policy, out-of-kind compensation is legally acceptable, and in practice, devising appropriate, ecologically-equivalent, in-kind compensation is hampered by the EIA procedure not requiring developers to use biodiversity measurements. Many local governments' compensation actions are similar to the developers' tree planting/urban green projects, such as a monoculture forest development using the Chinese red pine (*Pinus tabulaeformis*) in Yangqu County in 2022 (Table 3).

Due to China's flexible replaceability standards, some local governments' compensation activities have also been designed as nature-based solutions that provide wider environmental benefits to the economy and society (Table 3). For example, the Forestry and Grassland Bureau of Ganluo County of Sichuan invested its entire

CNY 500 thousand (c. USD 70 thousand) FVRF fund in walnut tree development, including two enhancement projects that covered in total 1700 μ (\sim 1.13 hectares), because the walnut industry is a means to reduce poverty and support local people's livelihoods (Cao et al., 2016). The Forestry Bureaus of Yongxing County and Longhui County of Hunan also implemented a range of different compensation measures which generated local livelihood opportunities, including spending part of their restoration fees on developing a base for Camellia (*Camellia oleifera*) cultivation and enhancing the quality of Camellia forest in order to improve its yield (Table 4).

4.3 | Compliance and monitoring

According to China's Forestry and Grassland Laws, the funds generated by compensation fees must be spent on: (i) ecological survey, design, and planning, (ii) habitat restoration and development, and (iii) conservation management and monitoring. China's National Forestry and Grassland Administration's policy paper *Guiding Opinions on Formulating Conditions for Restoration of Vegetation and Forestry Production, and Standards for Replanting of Trees* also suggests that compensation work should be done to provide additional benefits that would not have been delivered if the compensation had not been implemented, in order to reverse trends of environmental degradation. Otherwise, their spending will be regarded as the misuse or misappropriation of compensation funds; for example, in 2011, the Forestry Department of Xinjiang Autonomous was adjudged to have misappropriated CNY 4.24 million from the FVRF fund to pay expenses for the work of the department and its subordinate units (Wang, 2012). In the case study of Longhui County in Table 4, it is not immediately clear why programs of "forest highway development" and "building/maintaining the Centre for Forest Public Security, Resource Protection and Case Handling" should be considered additional conservation actions rather than misappropriations.

Yet, because of the lack of transparency in reporting by local authorities, it is difficult to assess whether many of China's compensation activities deliver additional benefits in the long term. On the biodiversity loss side, not all EIA reports are made transparent, or at least easily accessible, to the public; to our knowledge, there is no online database containing developments' full EIA reports for public scrutiny. Thus, it can be difficult for the public to understand how a development project might affect biodiversity before the development is carried out. On the compensation side, other than the information from the 10 county-level governments assembled in Table 3, we failed to find any public information on how

TABLE 3 Local governments' compensation practices funded by restoration fees.

Local agency	Year	Fee type	Expenditure (CNY) ^a	Disclosed compensation practice
Forestry Bureau of Mianchi County, Henan	2018	FVRF	11.14 million	Railway greening, improving the surrounds of Shaoshan forest park, mine land reclamation, village greening/green space improvement
Financial Bureau of Fugu County, Shaanxi	2019	FVRF	940 thousand	Barren hills afforestation, subsidy for village greening projects
Forestry Bureau of Yongxing County, Hunan	2019	FVRF	200 thousand	Subsidy of camellia improvement for increasing yield
Forestry Bureau of Longhui County, Hunan	2020	FVRF	4.96 million	Urban greening, riverside greening, existing wetland protection, old-growth tree protection, roadside greening, young forest tending, highway development for forest accessibility, seedling base development, camellia base development, building/maintaining forestry management office
Forestry and Grassland Bureau of Ganluo County, Sichuan	2020	FVRF	500 thousand	Walnut tree planting
Dunhuang Natural Resources Bureau (Forestry and Grassland Bureau), Gansu	2020	GVRF	5.30 million	Monoculture grassland planting (<i>Onobrychis</i>), pest control, vegetation restoration with fence building, hiring ranger, making signs and billboards, road development in field, publicity of grassland laws & regulations
Changsha Natural Resources and Planning Bureau Wangcheng Branch, Hunan	2021	FVRF	300 thousand	Soil preparation, afforestation forest restoration, pest control, resource management
Aksai Kazak Autonomous County Grassland Supervision Station, Gansu	2021	GVRF	747.10 thousand	Fence development, grassland quality improvement, grass seeds purchase, grassland reservoirs, weir, settling basin, pipeline laying, signage
Forestry Bureau, Yangqu County, Shanxi	2022	FVRF	1.6 million	Fire prevention, monoculture forest planting (<i>Pinus tabuliformis</i>).
Ordos City Natural Resources Bureau Dongsheng District Branch, Inner Mongolia	2022	FVRF	1.11 million	Afforestation (<i>Prunus armeniaca</i> and <i>Pinus tabuliformis</i>)

^a1 CNY = 0.14 USD.

much compensation payment has been collected from developers and how they are utilized by the other 2834 county-level governments. However, even among the published reports analyzed in this research, there are still large information gaps, such as the specific locations where compensation takes place.

5 | LEARNING FROM INTERNATIONAL BEST PRACTICES IN COMPENSATION

China's compensation policy is based on a restoration fee system applied nationwide. Our analysis of China's forest vegetation restoration fees suggests that it is likely that

compensation prices are insufficient to cover the costs of forest development in certain regions (Figure 4). This in turn suggests that the fees in these regions should be set higher to cover the actual costs of compensation, or the policy will not deliver on its aim of>NNL of forest cover. A compensation target (e.g.,>NNL of forest cover) may not necessarily be fulfilled only through one restoration fund, and it is common practice in China's political setting that, even if local governments stick to the insufficient price levels of FVRF, the residual costs of forest development can still be covered by other restoration funds transferred horizontally from other government revenue (e.g., from other taxes) or vertically from the central state. This may explain why China has still experienced an increase in forest area despite these issues with

TABLE 4 Compensation case study: Longhui County, Hunan Province, China.

Number	Compensation programmes in Longhui County ^a
1	CNY ^b 615 thousand was used for improving green coverage in 12 villages
2	CNY 310 thousand was used for riverside greening in six villages
3	CNY 823.919 thousand was refunded to a wind power development due to project cancellation
4	CNY 1963.881 thousand was used for Wetland Protection in Weiyuan Lake Wetland Park; actions included forest protection project design, forest fire prevention, forest resource database construction, and forest pest control
5	CNY 70 thousand was spent for old-growth tree protection in two villages
6	CNY 347.2 thousand was used for roadside greening
7	CNY 20 thousand was invested into management of young forest in Qinglongjiang Village
8	CNY 500 thousand was used for a forest highway development to provide improved access to forest areas for logging, afforestation and forest protection
9	CNY 50 thousand was used for seedling production in the Shouzhu Garden
10	CNY 100 thousand was used for the development of a base for cultivation of Camellia
11	CNY 160 thousand was spent for building/maintaining the Centre for Forest Public Security, Resource Protection and Case Handling

^aLonghui County is located in Shaoyang City within Hunan Province. It has more than 200 families and over 1000 species of vegetation. The county is a national-level production base for pepper, tea, and orange. In 2019, the County's CNY 4.96 million forest vegetation restoration fee was invested into forest development in the area. This information is collected from the documentation released by the government of Longhui.

^b1 CNY = 0.14 USD.

the current price levels. Yet, the economic theory behind compensation is 'polluter pays', which accords with the ethical basis of China's compensation approach (Table 1). Thus, in order for China to achieve the desired compensation results, the government may need to consider revising its price levels, not only in order to increase the finance available for compensation, but also for increased economic efficiency within the system.

However, before raising the fees, the apparent disparity between forest restoration fees and restoration costs

must be investigated. For example, the disparity in more affluent regions such as Beijing and Shanghai could relate to less purchasing power (e.g., higher land prices), more costly afforestation practices (e.g., implementing more polycultures instead of monocultures only), or systematic issues like administrative corruption. It could be that simply raising fee levels might lead to better conservation outcomes, both through improving funds for compensation and as a financial disincentive to clear land and an incentive for active compensation. However, it is ethically and economically important to more clearly understand which costs should be shouldered by the developers, versus those which should be mitigated through other measures, such as addressing misappropriations of the restoration funds (Maron et al., 2016).

If prices are increased to meet the actual costs of carrying out restoration, China's restoration fee system could be an effective and efficient method for redressing the natural habitat area losses caused by developments and supporting China's goal of conserving and planting 70 billion more trees before 2030 (World Economic Forum, 2022). However, there is still the issue that China's compensation policy only relates to habitat area and does not account for a habitat's quality, functional role within an ecological network, conservation value, species richness and many other such attributes. In addition to habitat area, compensation needs to account for such features to realize its target of "maintaining biodiversity" (Niu et al., 2023). Since China has prioritized economic development as a developing nation, the government's long-standing "develop first, fix later" model has situated its compensation policy on top of a "weak replaceability principle" that assumes two different biodiversity resources are exchangeable with one another (e.g., a wetland forest with roadside tree planting). Thus, to meet the targets set in the central government's recent commitments to embed conservation into the economic and social fabric of China and improve China's biodiversity (State Council, 2021a), the government may need to revise its replaceability principle towards the international best-practice standards of "like-for-like" or "like-for-like or better." whilst strengthening the use of mitigation hierarchy (Bull et al., 2013; Gardner et al., 2013; McKenney & Kiesecker, 2010). Embracing higher replaceability standards requires the design and delivery of better avoidance and minimization policies that prevent impacts to irreplaceable biodiversity, followed by a strengthened compensation policy that carefully replaces all biodiversity losses (not merely habitat cover).

As defined by international good practice, measurability is a fundamental attribute of biodiversity offsetting (Maron et al., 2016; Bull et al., 2013 & 2016; Baker

et al., 2019). Quantification of biodiversity impacts is an important precursor to precise evaluation of the performance of compensation and whether or not it meets its conservation goal (e.g., NNL or maintaining biodiversity). To measurably record the biodiversity impacts of developments, China's developers would need to use well-structured biodiversity indicators that can capture diverse biological components and some degree of ecological processes behind the habitats (Mayfield et al., 2022). The current absence of policy requiring the use of robust biodiversity measurement represents a significant risk to biodiversity, especially when the redline policy cannot recognize some important areas in a clear and timely manner (Jiang et al., 2019; Xinhua, 2017). For instance, the EIA report on Jiasajiang Level 1 Hydropower Station recorded many vital biodiversity components on the development site (Table S1), including seasonal tropical forest and green peafowl (*Pavo muticus*), which is categorized as Endangered on the IUCN Red List. Though it applied indicators to capture the biodiversity elements which were present, it assumed that birds can migrate to other places and thus failed to address the ecological disturbance caused by the development; for example, flooding of the dam destroying the Red River upstream area which has been identified as the last habitat for green peafowl in China (Tang et al., 2019; Wu et al., 2019). Since the biodiverse zone had failed to be officially recognized within an ecological redline, the development was being implemented and listed as a key project by the local government. In fact, all the EIA reports we reviewed assumed that birds and reptiles would not be impacted by the development because of their ability to find new habitats. Though this may occasionally be true, the case study shows that this assumption may also permit serious and irreversible biodiversity losses.

The green peafowl case also indicates the importance of defining biodiversity indicators using a common and consistent framework. Otherwise, some important biodiversity effects might unintentionally be disregarded in practice. Currently, since the compensation policy is devoid of biodiversity measurement requirements, there is wide variation in the indicators used. However, if there is unrestricted flexibility in the choice of indicators used to measure a development's impacts on biodiversity, there is a great scope for selective reporting that may undermine the conservation of specific, unreported biodiversity components in order to increase the probability of project approval (Bull et al., 2014). Additionally, a common indicator framework could be used to measure biodiversity gains from compensation, whether implemented by developers themselves or local governments. This can make what is lost on a development site comparable to what is gained on a compensation site,

producing the ecological equivalence which is missing in China's compensation policy but is well established in international good practice (McKenney & Kiesecker, 2010; Quétier & Lavorel, 2011). This is essential for tracking the effectiveness of the policy in actually compensating for biodiversity losses.

Similar to the current requirement introduced in China's compensation legislation, best practice also requires compensation which provides additional and positive effects on biodiversity (Bull et al., 2013; Moilanen & Kotiaho, 2018; Overton et al., 2013). Evidence is required to prove the effectiveness of compensation practices (such as fence building in Table 3), but currently, the compensation information disclosed is insufficient for researchers to conduct impact evaluations and develop a robust understanding of policy effectiveness. Furthermore, best practice requires compensation to persist for at least as long as the adverse biodiversity impacts from the development project (Bull et al., 2013; Damiens, Backstrom, & Gordon, 2021; Gonçalves et al., 2015). Evaluation of whether compensation persists over time requires time-series information supported by adequate monitoring (Gordon et al., 2015; McKenzie & Kiesecker, 2010). The current ambiguous disclosures practiced in China impair compliance monitoring; in compensation systems in other countries, compliance failures have been found to be widespread (Theis et al., 2020; zu Ermgassen et al., 2019), and this is, therefore, a concern for China as well. Establishing a public national offset register supported by well-established biodiversity indicators, including information on how local governments spend their restoration fees, *ex-ante* ecological assessment, and *ex-post* compensation implementation and outcomes, would be a major step forward (Gao et al., 2022; Hunter et al., 2021; Kujala et al., 2022). Additionally, developers should be required to precisely report their compensation activities in their EIA reports, detailing in a measurable way how these actions are expected to counterbalance the losses they are generating. These EIA reports should be made public to improve transparency, helping to identify ecologically-risky development activities and misappropriations of the compensation funds, and facilitate improved compensation performance assessment and monitoring.

6 | CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

We provide the first overall evaluation of China's eco-compensation policy and practice. Based on the evidence we have assembled, we also provide recommendations

for China to align with international best practices in biodiversity impact compensation. First, in policy, we found that the pricing of forest restoration fees is insufficient in several provinces and municipalities. We recommend these regional governments conduct a more careful and up-to-date evaluation of the costs required for local forest management and evaluate whether current price levels should be increased. Also, we found that there is currently no policy requirement either for biodiversity metrics to be used to measure development impacts on biodiversity or for ecological equivalence of compensation and losses. Thus, we recommend that the central government should consider legislating for biodiversity impact measurement using a unified indicator framework, and, if possible, make it compulsory for all development activities. There are many examples in other countries from which China could draw lessons; for example, though not perfect, the latest version of the biodiversity metric in the United Kingdom is an example for China to learn from (zu Ermgassen et al., 2021).

In practice, without a regulatory safeguard for biodiversity metrics and ecological equivalence, we unsurprisingly found that only 23% of a sample of 31 developments applied quantitative biodiversity metrics, drawing on a range of indicator frameworks. This evidence strengthened our recommendation to make the application of a unified framework mandatory. Also, fewer than 1% of China's local governments have disclosed information regarding compensation implementation. This highlights a key problem for future studies of eco-compensation in China: publically-available information in its current form does not permit an assessment of biodiversity losses and gains under the policy, which hinders a robust assessment of the policy's effectiveness at achieving its goals.

Recently, China's government has strengthened its strategic aspiration to actively participate in biodiversity governance through collaboration and international knowledge exchange (State Council, 2021a). The government can meet this aspiration by improving first its avoidance and minimization policies, and then improving its compensation approach. This is important as China's future development plans are substantial and likely to have major biodiversity impacts; a recent estimation predicts that by 2100, China's urban area will be 121,199–142,982 km², 34%–58% higher than the urban area in 2020 (Huang et al., 2022).

Equally, there are some special features of China's compensatory mechanism which might be informative for compensation design in other countries. For instance, the government charges upfront compensation fees and then reimburses developers for delivering biodiversity impacts which are less than those expected in their EIAs. This feature differs from other countries' compensation

approaches and could encourage developers to avoid and minimize their biodiversity impacts at the early stages of their projects. Thus, future research studying China's compensation approach could provide empirical evidence that supports effective avoidance and minimization, which are the most critical steps of the mitigation hierarchy (Bull et al., 2022; Milner-Gulland et al., 2021; Phalan et al., 2018).

Compensation design also faces trade-offs between biodiversity and social values, since conservation is not always prioritized over economic development (Griffiths et al., 2020; Jin et al., 2021; Taherzadeh & Howley, 2018), while the well-being impacts of development and associated compensatory actions on local people are often ignored (Bidaud et al., 2018; Griffiths et al., 2019 & 2019; Jones et al., 2019). Future assessments of China's compensation approach could provide understanding of when and where social well-being has been prioritized and how solutions that work for both nature and people can be designed and implemented. We found some of China's compensation programs in the late 2010s strived for nature-based solutions that help address livelihood insecurities in some of the most underdeveloped communities. These practices may have led to less compensation for loss of natural habitats, if we set “like-for-like” or “like-for-like or better” compensation as the benchmark (Baker et al., 2019; Bull et al., 2016; Maron et al., 2016). However, in some situations, it may be preferable to put an emphasis on supporting people's well-being alongside nature conservation (Domínguez & Luoma, 2020; Maron et al., 2020; Newing & Perram, 2019). Studying the interaction between human well-being and biodiversity in the context of China's eco-compensation practices would provide substantive insights to support the future design of socially just ecological compensation, particularly given that China is both a major developing economy and a highly biodiverse country.

AUTHOR CONTRIBUTIONS

This study was conceptualized by Shuo Gao, Joseph W. Bull, and E. J. Milner-Gulland. Data were collected by and analyzed by Shuo Gao. All authors discussed the results and contributed to writing and editing the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

Data are included in the supplementary materials.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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