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PERSPECTIVE

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A culture of conservation: How an ancient forest plantation turned into an old-growth forest reserve – The story of the Wamulin forest

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Abstract

1. The global expansion of forest plantations at the expense of natural forests, especially old-growth forests, raises concerns about habitat loss and a decline in ecosystem services.
2. Natural regeneration of second-growth forests with minimal human assistance has been suggested as a cost-effective way to restore forests and increase forest ecosystem service potential. However, it is unclear whether natural regeneration will lead to the development of second-growth forests similar to natural forests because most naturally regenerated second-growth forests are still young.
3. We present a case study of a very old second-growth forest in southeastern China in which a forest plantation established approximately six centuries ago has now developed into an old forest with extraordinary high biodiversity levels, an immense carbon pool, and a rich culture. The forest was established in the 14th century because of a charitable contribution, became protected under the Chinese cultural norm of 'unity between humans and the nature', and was conserved because of the belief that the prosperity of people is closely linked to the prosperity of trees. The recent designation of the forest as a nature reserve further protects it from development despite competing land-use demands related to recent economic growth.
4. This case illustrates that, although human activity is the main cause for the disappearance and degradation of many forests, when human interests and cultural values align second-growth restoration and subsequent forest conservation can lead to the successional development of old-growth forests. Because this development takes multiple centuries, the protection of current second-growth forests within conservation easements (e.g. nature reserves) and the reformation of culture values for the linkage of forests to human well-being are key aspects of the continued conservation-aided succession of second-growth forests.

KEYWORDS
biodiversity, ecosystem services, old-growth forest, secondary succession, unity between humans and the nature, Wanmulin Nature Reserve

1 | INTRODUCTION

Forest plantations are an important component of global forest cover with a global extent of 294 million ha (FAO, 2020). The global extent of forest plantations increased approximately 139% from 1990 to 2020 (from 123 million ha to 294 ha) despite an overall decrease of global forest area by 178 million ha or 1.7% during that period (FAO, 2020). As a result, maximizing the ecosystem services of forest plantations has become a major objective of forest management in light of current global climate change (Baral et al., 2016; Barrios et al., 2018; Liu et al., 2018).

Forest plantations are often considered as having lower capacities to provide ecosystem services compared to natural forests. Many forest plantations (e.g. oil palm plantations) are viewed as 'green biodiversity deserts' (Horák et al., 2019), especially when they have replaced natural forests because biodiversity levels typically decline (Bremer & Farley, 2010; Brockerhoff et al., 2008). Although many studies indicate that forest plantations can provide multiple forest-based products and play an important role in carbon sequestration (Baishya et al., 2009; De Stefano & Jacobson, 2018; Lai, 2004; Quine, 2015; Sang et al., 2013), there are doubts regarding their relative capacity for long-term carbon sequestration and harboring a comparable diversity of organisms to natural forests (Barlow et al., 2007; Liu et al., 2018; Sohngen & Brown, 2006; Yu et al., 2019). In addition, forest plantations are not often associated with the unique cultural and biodiversity conservation values that characterize many old natural forests (Sutherland et al., 2016; Yazzie, 2007) because the vast majority of forest plantations are relatively young and therefore lack clearly established cultural connections to people.

Old-growth forests differ from forest plantations in many ways. In addition to the astonishing tall and giant trees they have, many old-growth forests are characterized with more complex horizontal and vertical forest structure than second-growth forests, which results in a greater diversity of habitats for plant and animal species (McMullin et al., 2010; Spies & Franklin, 1988; Zenner, 2004). Many old-growth forests are refuge habitats (i.e. areas, often protected, where populations thrive because of low mortality or increased survival or recruitment) for endemic, endangered or keystone species such as the spotted owl of the Pacific Northwestern United States (Yackulic et al., 2019), the ant communities of the Brazilian Atlantic Forest (Bihn et al., 2008), or the giant panda of Sichuan, China (Zhang et al., 2011). Although old-growth forests are assumed to have low, even near zero net carbon accrual rates, studies have shown that they can still sequester and accumulate large amounts of carbon in soils (Desai et al., 2005; Zhou et al., 2006) and thus are important global carbon sinks (Badalamenti et al., 2019; Luyssaert et al., 2008; Yuan et al., 2016). In this light, old-growth forests provide a clear societal and cultural value, given the current anthropogenic global change pressures. Additionally, old-growth sacred forests, are renowned for their culture and spiritual values (Brandt et al., 2013; Ishii et al., 2010; Moore, 2007; Moyer et al., 2008).

Old-growth forests are symbols of humankind's natural legacy, and hallmarks of societal environmental stewardship. In fact, many old-growth forests are national or world heritage sites, which symbolizes both their cultural and environmental value as natural ecosystems. For example, the old-growth beech *Fagus crenata* forest in the Shirakami Mountains in Japan was registered as a UNESCO World Heritage in 1993 because it contains some of last unaltered remains of a forest type which once covered the landscapes of northern Japan (Chakraborty, 2018). Similarly, the large and iconic old-growth forests of British Columbia are symbolic of its natural heritage, exemplifying how native people used the forest for provisioning of food, medicine and shelter (Connell et al., 2015). Thus, although not defined explicitly, old-growth forests are in general, assumed to be the unaltered product of nature's majesty over long periods of time with minimal human disturbance (Bradshaw, 2004; Chapman & McEwan, 2016; Lin et al., 2015).

2 | FOREST REGENERATION AND ECOSYSTEM SERVICES

Forests can regenerate artificially, completely naturally or naturally with some human assistance (Table 1). Artificial regeneration which is most common in the form of forest plantations is achieved by planting and actively managing tree survival and growth for economic gain. The expansion of forest plantations often takes place at the expense of natural forests, which often leads to a reduction in the provisioning of key forest resources, like clean air and water, and increases the risk of environmental degradation, including reduced soil fertility, increased soil erosion, more floods and even desertification (Li, 2004) as well as a loss of connectivity between the forest and the people (Foo, 2016). Some silviculture practices seek to develop or maintain old-growth forest attributes in forest plantations (Bauhus et al., 2009). However, an important but largely unaddressed question in management is whether forest plantations can successionally develop to old-growth forests, with their characteristic high

TABLE 1 Forest regeneration types and their biological and cultural diversity

Type	Subtype	Strength	Weakness
Artificial regeneration/ tree plantation	Monoculture	Rapid tree growth/High short-term market value	Very low biodiversity, limited connection to people
	Mixed		Low biodiversity, limited connection to people
Natural regeneration	Without human assistance	High biodiversity, co-development with local human community	Very slow succession to the mature stage, low short-term market value
	With human assistance (e.g. weeding and exclusion of grazing at the initial stages)	High biodiversity, co-development with local human community	Slow succession to the mature stage, low market value

capacity for providing ecosystem services (e.g. biodiversity, carbon storage and culture values). The answer to this question has important implications in forest management, especially in regions where intensive forest plantation practices have led to land degradation (Bi et al., 2007; Yetti et al., 2011).

Natural regeneration and assisted natural regeneration have been recommended as viable strategies to improve ecosystem service capacities of degraded plantation forests (Chazdon, 2017; Crouzeilles et al., 2020; Shono et al., 2007; Yang et al., 2018). Naturally regenerated forests have been shown to achieve the level of species richness similar to old-growth forests in several decades, but a much longer time is required for them to regain the species composition and structural complexity of typical old-growth forests (Aide et al., 2000; Brown & Lugo, 1990). Regeneration through human assistance to minimize barriers to natural regeneration (e.g. competition with weeds and grazing) has been suggested as a low cost and effective way to quickly restore degraded tropical and subtropical forests in terms of biodiversity, soil and water conservation and carbon sequestration (Evans et al., 2015; Shono et al., 2007, 2020; Yang et al., 2018). Secondary forests developed through assisted natural regeneration have been shown to provide multiple social benefits in addition to ecological benefits (Chazdon & Uriarte, 2016).

In relatively 'wild', well-conserved areas with minimal direct human influence, regeneration through secondary succession takes place typically following major disturbance events such as the 1988 Yellowstone National Park fire (Turner et al., 1997). Given sufficient time, many of the disturbed (e.g. burned) sites may naturally regenerate to old-growth forests characteristic to the region although they could be slightly different in their extent, spatial distribution or species composition from the forest existing before the fire due to changes in the environment such as the climate (Donato et al., 2016).

Natural regeneration through secondary succession can sometimes take place not as the result of conservation effort, but due to lack of management such as old field abandonment (Aide et al., 2000). In fact, modern successional theory has its origins in studies of secondary succession on abandoned old fields in the eastern United States (Inouye et al., 1987; Nicholson & Monk, 1974). One important but not well-addressed question is whether forest regeneration through secondary succession on unmanaged lands can result in the recovery of forests with characteristics common to old-growth forests. A study of secondary forests in central Panama ranging in age from 20 to 100 years showed that secondary forests increased in ecological similarity to old-growth forests over time in terms of shade tolerance but not in species composition (Dent et al., 2013). Similarly, the study of secondary succession following old field abandonment and the study of historical changes in forest vegetation and land use in central New England indicate that species richness but not species composition in 150- to 200-year-old forests were similar to old-growth forests (Foster et al., 1998; Nicholson & Monk, 1974). These studies support the idea that 100–200 years is not sufficient to attain forests with old-growth characteristics. However, to our knowledge no studies have examined secondary forests of more than 200 years old to evaluating whether the forest will eventually develop old-growth characteristics and attain a high capacity for providing ecosystem services over multiple centuries.

Here we describe a case study, in which a 'human-made forest' in southeastern China has successionally developed over six centuries to become an old natural forest with extraordinarily high levels of biodiversity, large carbon stocks and a deep cultural significance. We argue that although human disruption is currently the main cause of the disappearance of many old-growth forests, the many species that inhabit them, and the cultural links between human communities and the forest, such disruptions are not the only possible outcome. If well-managed or protected, marginal land can develop into an old natural forest with characteristics similar to primary old-growth forests; however, this process takes a very long period of time, likely multiple centuries. We also highlight that the successful protection of the forest, despite recent economic growth at the expense of natural forests, relies on both the deep cultural belief of the unity between the nature and people and the inclusion of the forest into the formal nature reserve system. Thus, we affirm that the protection of local culture and its incorporation into national nature reserve system are key to the protection of sacred forests with often unique ecosystem services.

3 | THE WANMULIN NATURE RESERVE

The Wanmulin (meaning forest with tens of thousands of trees) Nature Reserve (27°03′N, 118°09′E) is a low-elevation (230–556 m) evergreen broadleaf forest located in Fangdo Town, Fujian Province of southeastern China (Figure 1). The annual mean temperature of

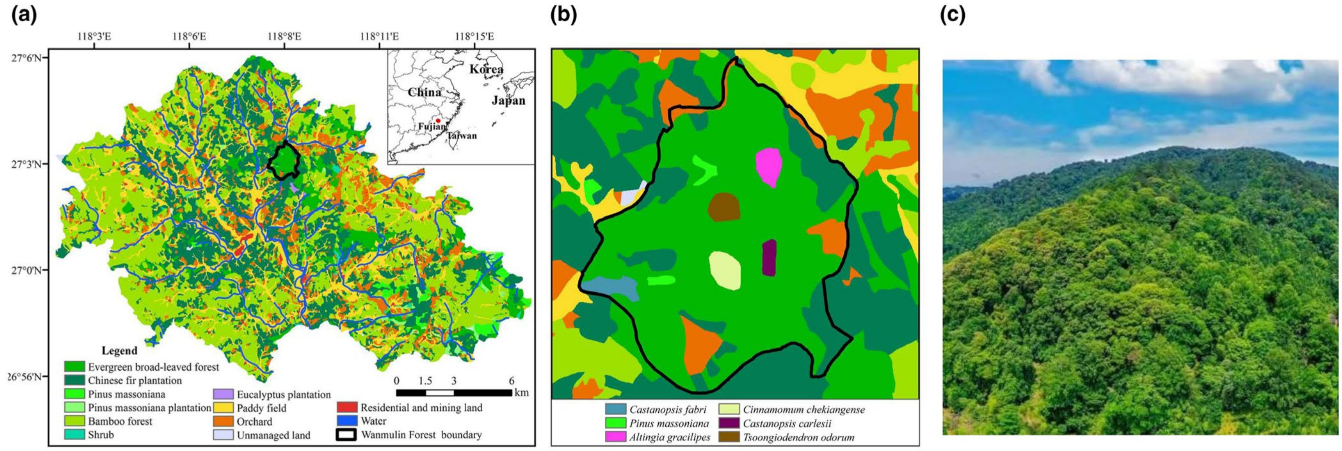

FIGURE 1 (a) The location of the Wanmulin Nature Reserve within the Fangdo Town, Fujian Province of China, (b) the distribution of dominant species-type forest communities within the reserve, and (c) a visual overlook of the reserve. The Wanmulin Nature Reserve was initiated as a human-made Chinese-fir plantation but is now an ~600-year old mixed-species forest with many old-growth forest characteristics and a high capacity to provide essential ecosystem services. Photo courtesy of Xiaohui Guan

the region is 18.7℃, with temperature highs of 28.5℃ in July and lows of 8.0℃ in January. The mean annual precipitation is 1,673 mm, which ranged from 1,010 mm to 2,028 mm between 1951 and 2010. The soil developed from granite parent material, is highly weathered and can be classified as humic Planosols in the FAO system, with a soil depth exceeding 1.0 m (Lin et al., 2011; Yang et al., 2009).

3.1 | The history

The 189-ha Wanmulin Nature Reserve, is a Fengshui (an ancient Chinese geomantic tradition which claims to use energy forces to harmonize environments) forest. It was a marginal land area used as a cemetery of the Yang family (Chen, 2000), and during this time was not forested. During a famine in 1,354, Mr Fushing Yang (1,305–1,378)—an elite of the Yang family, gave one Chinese bushel (approximately 10 L) of millet to people suffering from the famine and, in exchange, he asked each of them to plant one Chinese fir *Cunninghamia lanceolata* sapling in his family graveyard (Chen, 2000; Qiu, 2010). This exchange (bushels of millet for the planting of trees) had two important purposes. For one, Mr Yang delivered the message that there is no free lunch; more importantly, this eased doubts from the government that donating food to the poor people was a sign of suspicious economic activity (Qiu, 2010; Yu, 2001). In 1,385, when the forest plantation was 31 years old, well within the range of typical age of harvest for Chinese fir plantations (25–50 years old; Yang, 1998), Mr Fuashing Yang's son donated approximately 30,000 trees, covering an area of about 33 ha, for construction of the Biheshan (White Crane) Temple. As a reciprocal gesture of kindness, the temple management team gave the Yang family a piece of land (Qiu, 2010). This is the only known large scale tree harvest to the forest plantation since its establishment.

In 1,399, after Mr Jong Yang, the grandson of Mr Fushing Yang passed the imperial examination at the provincial level, the site was locked down as a protected area by the provincial government (Yang, 2004). Since then, land development or felling trees in the forest has been forbidden. In 1954, the forest was designated as a no-logging forest by the Chinese government, and in 1973, it was further designated as a nature reserve. Furthermore, it was included into the Nature Reserve system of the Fujian Province in 1980 (Zheng et al., 2019), which was a few years before the reform and opening of China that led to the rapid industrialization and development of many forested lands over the past several decades. Because of the limited utilization and development, the site has been left largely un-managed allowing secondary succession to take place for approximately six centuries, making the Wanmulin Nature Reserve now an old forest (Figure 1).

4 | FOREST STRUCTURAL CHARACTERISTICS

Six major plant communities dominated by tree species common and native to the region can be identified within the Wanmulin Nature Reserve (Zhu et al., 1997). By 1997, the canopy height of the six plant communities ranged from 23 m to 32 m, with maximum diameters at breast height (dbh) of the dominant tree species ranging from 46.7 cm to 100.5 cm, and tree ages spanning 120 ± 20 years to 185 ± 15 years (estimated from Zhu et al., 1997; Table 2). However, the tallest tree within the Wanmulin Nature Reserve is a 41 m *Pinus massoniana* (Figure 2a) and the largest tree in terms of dbh is a 190 cm *Castanopsis lamontii* (Figure 2b; Zheng et al., 2019). The ages of large trees are not perfectly determined; however, the oldest tree, a *Cinnamomum micranthus*, is estimated to be more than 500 years old, with a height of 36 m, a dbh of 175 cm, and crown dimensions of 30 × 35 m (Zheng et al., 2019; Figure 2c).

The tree-diameter distributions for the Wanmulin Nature Reserve for the number of species and individuals are reverse

J-shaped (Bi et al., 2003), which is common for old-growth forests (McCarthy & Weetman, 2006; Rozas, 2006; Varga & Klinka, 2001), although other distribution types such as negative exponential model and Weibull functions could also be found in old-growth forests (Westphal et al., 2006).

Coarse woody debris (diameter > 20 cm) of the old forests in the Wanmulin Nature Reserve is 23 Mg/ha with 77% from fallen trees and 22% from standing dead trees (He et al., 2010). Although 23 Mg/ha is lower than some old-growth forests such as those in Northwestern Pacific (up to 173 Mg/ha, Spies & Franklin, 1988) and in south-central Chile (60–89 Mg/ha, Schlegel & Donoso, 2008), it is comparable to the 21.8 Mg/ha of the old-growth forest in the Cumberland Plateau of southeastern Kentucky, United States (Muller & Liu, 1991), within the range of old-growth evergreen forests in British Columbia (17–74 Mg/ha, Feller, 2003), and greater than the 3.7–15 Mg/ha reported for old-growth forests in southern Indiana, United States (MacMillan, 1988). Moreover, the coarse woody debris of the forests in the Wanmulin Nature Reserve is spread over a wide range of decay levels (14%, 26%, 32%, 26% and 2% for decay level from I to V, He et al., 2010), which is also characteristic of old-growth forests (Wirth et al., 2009).

TABLE 2 Canopy height, maximum diameter at breast height (dbh) of the dominant tee species, and age of plant communities at the Wanmulin Nature Reserve (Modified from Zhu et al., 1997)

Community type	Canopy height (m)	Maximum dbh (cm)	Age (year)
Castanopsis carlesii	23	46.7	125 ± 20
Castanopsis fabri	25	49.8	125 ± 20
Tsoongiodendron odorum	28	77.0	145 ± 20
Altingia gracilipes	28	820.0	160 ± 15
Cinnamomum chekiangense	26	65.0	160 ± 15
Pinus massoniana	35	100.5	190 ± 15

Canopy gap size also has a reverse J-shape frequency distribution with a mean gap size of 75 m^2, but gap size varies widely, ranging from <60 m^2 to >800 m^2 (Yan et al., 2002). A wide range of gap size has been suggested to contribute to high canopy species diversity of southern Appalachian cove old-growth forests of Kentucky and Tennessee, United States (Clebsch & Busing, 1989). Gap phase dynamics, which contributes to the population age/size-structure of old-growth forests (Rebertus & Veblen, 1993), play a key role on the regeneration of the Wanmulin Nature Reserve as seedlings of many of the tree species found in the forest (29 species in total) only regenerate in canopy gaps (Yan et al., 2006).

5 | BIODIVERSITY AND BIOMASS

5.1 | Plants and large fungi

There are 1,342 vascular plant species and 137 species of large fungi in the Wanmulin Nature Reserve. Among vascular plants, two species are listed in the national level I protection of wild plants, 23 species are listed as national level II protected, and six species occur on provincial protection list (Table 3). Twenty-two of the species were not listed previously in the Flora of Fujian where the Wanmulin Nature Reserve is located, and are thus new records to the area. In addition, there are three species (*Mazus wanmuliensis*, *Acidosasa chienouensis*, *Symplocos fukienensis*) which were recorded for the first time, and found to be endemic to Fujian Province (Zheng et al., 2019).

A total of 963 insect species, 8 amphibian species, 22 reptile species, 141 bird species and 35 mammal species have been recorded in the Wanmulin Nature Reserve (Zheng, 2013; Zheng et al., 2019). Among the animals, five species are listed in the national level I protection list, 23 species are listed in the national level II protection list, and 24 species are listed in provincial focal protection list, and 207 species are listed in the general protection list (Zheng, 2013; Zheng et al., 2019).

FIGURE 2 Tree giants of the Wanmulin Nature Reserve in Fujian, China. (a) The tallest tree, a *Pinus massoniana*, with a height of 41 m, (b) the thickest tree, *Castanopsis lamontii*, diameter at breast height 190 cm and (c) the oldest tree, *Cinnamomum micranthus*, >500 years old. Photos courtesy of Xiaohui Guan

TABLE 3 Biodiversity in the Wanmulin Nature Reserve. Data from Zheng (2013) and Zheng et al. (2019)

	Species	Genera	Family	Order	Class
Vascular plant	1,342	619	169		
Large fungi	137	56	30	8	4
Insect	963		112	17	
Amphibians	8		4	1	
Reptile	22		8	2	
Bird	141		36	15	
Mammals	35	16	17	7	

5.2 | Biomass/carbon storage

The above-ground biomass of trees in the Wanmulin Nature Reserve is around 400 Mg/ha, and based on a carbon concentration of 55.5%, the above-ground carbon stock is estimated to be around 224 Mg/ha (Huang et al., 2011). The above-ground biomass is much higher than other forests in China. According to a nationwide survey, the average above-ground biomass of all forests in China is 120 Mg/ha, and maximizing at >300 Mg/ha with subtropical evergreen broadleaf forests harboring about 140 Mg/ha (Su et al., 2016). Based on the survey of Su et al. (2016), the tropical monsoon forests–rainforests have the highest above-ground biomass in China, with more than 50% at the range of 100–250 Mg/ha. In the region, the above-ground biomass of a natural evergreen broadleaf forest in the Gutianshan National Nature Reserve of Zhejiang Province is 180–246 Mg/ha (Lin et al., 2012). Therefore, like many old-growth forests, the old forests within the Wanmulin Nature Reserve play an important role in cycling and storing carbon (Hoover et al., 2012; Luyssaert et al., 2008; Paw et al., 2004).

In terms of below-ground carbon, soil organic carbon of the Wanmulin Nature Reserve is 157 Mg/ha, 34% higher than adjacent secondary forests and more than two times the soil organic carbon stocks in nearby arable land (Yang et al., 2009). It is also considerably higher than the 100–114 Mg/ha reported for subtropical broadleaf forests in China (Li & Zhao, 2001).

6 | CULTURE AND EDUCTIONAL VALUES AND ECOSYSTEM SERVICE VALUATION

The act of Mr Yang from more than 600 years ago, highlights the long-held Chinese belief of 'unity between humans and the nature', as well as the lesser-known Yang family value that 'tree prosperity leads to family prosperity' (Yu, 2001). The specific belief is emotional or even spiritual in nature, encompassing the assumption that trees grow well because of good land stewardship, and good stewards of land are also good family members. Following these beliefs, the ancient Yang family's action of planting trees in Wanmulin has led to the prosperity of the forest reserve, its conservation and a cultural heritage site that is closely linked to the prosperity of people in the region. This deeply rooted belief has played a key role in continued conservation of the Wanmulin Nature Reserve over the past six centuries.

Additionally, the Wanmulin Forest has inspired the creation of many works of artwork. Many paintings, poems and essays have also been inspired by the Wanmulin Nature Reserve and at least seven movies or documentaries (e.g. Love Castle of 1964 and Lufengpithecus Lufengensis of 1992) have been filmed within the Wanmulin Nature Reserve (Zheng et al., 2019).

The astonishing old-growth Wanmulin Forest along with its extraordinary high biodiversity has attracted many scientific researchers. At least 16 different high schools, universities and research organizations have used Wanmulin Nature Reserve as an environmental education site (Zheng et al., 2019), and 134 scientific journal articles about the Wanmulin Nature Reserve have been published covering both nature and social sciences [based on our literature search in Web-of-Science (three articles) and China Integrated Knowledge Resources Database (131 articles) using the keyword 'Wanmulin' or 'Wanmulin Nature Reserve'].

Based on the valuation assessment made by the Provincial Government of Hunan, China, the value of ecosystem services provided by the Wanmulin Nature Reserve is approximately $40 million USD annually, 41.4% of which comes from soil protection and improvement, 29.3% of which originates from air purification, 13.5% of which is related to water resource protection, 12.4% of which comes from timber products (estimated from the current market value of current timber divided by 600 years, as harvest has been forbidden since 1,399), and 3.6% of which is related to forest landscape attraction (Yu, 2001).

7 | WANMULIN NATURE RESERVE IN COMPARISON WITH OTHER SACRED FORESTS AND UNINTENTIALLY PROTECTED FORESTS

Forests can be largely free from direct human influence for both intentional and unintentional reasons (Table 4). The formal conservation of forests with laws and conservation easements is well understood. However, in the absence of laws and conservation easements, the lack of direct human influence on natural areas which leads to secondary succession and forest development can arise intentionally, (i.e. as a result of cultural or religious beliefs) or unintentionally (i.e. unplanned, as in the case of old field abandonment or in remote, inaccessible areas) because there is no need to manage the forests yet (Peterken, 1996). The intentional (i.e. deliberate) conservation and protection of sacred forests begs a deeper understanding from a cultural and value-based perspective. Forests may undergo intentional, albeit typically informal, protection because of religious, social, cultural or moral reasons, even despite having extractable ecosystem services.

For example, religious traditions from the Khasis, Faros and Jaintias tribal communities are closely linked to biodiversity levels, and forest structure in the sacred forests of Meghalaya, India, which are much better conserved than adjacent unprotected forests (Tiwari et al., 1998). In addition to intentional protection by religious or culture beliefs, forests in national parks and nature reserves are intentionally protected by laws for conservation purposes. Although the formal protection by conservation legislation is of relatively recent origin (within the last 200 years), the forests protected often have much longer periods free from direct human disturbance because wildness or pristineness is one of the main reasons they were chosen for protection by laws. Their protection reflects intentional human efforts to keep certain areas of nature from the anthropogenic forces that are transforming them (Turner, 2014), and provides a link between intentional conservation and formal (i.e. legal) conservation areas. Such conservation efforts are rewarding, as national parks and other protected areas have been shown to be keystones to conservation and sustainable development (Nelson & Serafin, 2013). Natural forests with minimum human influences represent an important reference point for evaluating human impact on natural ecosystems and for illustrating the interconnection between people and the natural woodlands (Peterken, 1996).

The Wanmulin Nature Reserve and many other sacred forests, globally, are unintentionally protected due to culture beliefs but not necessarily by laws, at least at the beginning. Like the Wanmulin Nature Reserve, many scared forests across the globe are key reservoirs of biodiversity and have high cultural value (Ambinakudige & Sathish, 2009; Ormsby, 2011; Rots, 2017). For example, sacred forests in the Himalayan of southwest China are keystone habitats to bird conservation efforts (Brandt et al., 2013). In addition to the culture and religious significance, more than 100,000 sacred forests in India are important refuge habitats for biodiversity conservation, with some of them being international biodiversity hotspots (Ormsby & Bhagwat, 2010).

Sacred sites protected through community-based conservation due to religious and cultural beliefs are found on every continent except Antarctica and have been considered an important component of global biological conservation (Bhagwat & Rutte, 2006). Without formal protection by laws, changes in the cultural or religious beliefs of the nearby communities in combination with the pressures from the demands for forest-derived natural resources (e.g. timber products) and for agriculture, industrial, commercial or residential development impose threats to these forests (Ormsby & Bhagwat, 2010). It has been suggested that if local communities depend heavily on the forests to meet their needs, sacredness may not be sufficient to ensure their persistence or sustainable use (Soury, 2007). Using the Wanmulin Nature Reserve as a case study, we illustrate that although cultural traditions were key to the protection of the Wanmulin Nature Reserve for multiple centuries, its inclusion to the nature reserve system granted and ensures its continuing protection via a formal conservation easement despite the increasing competing demands of land use in recent decades.

In contrast to the intentional protection of forests which reflects people's appreciation of the value of nature, many natural forests and second-growth forests in remote areas or developing from abandoned old fields are free from direct human disturbance because of the limited profit of managing them (i.e. unintentionally; Peterken, 1996). Many forests, which have naturally regenerated from abandoned old fields now provide a diverse range ecosystem services such as habitat for biodiversity and large carbon sequestration and storage capacity (Geddes et al., 2011; Johnston et al., 1996; Perring et al., 2012). Such unintentional conservation of forests is possible, and more-probably, in regions with large land areas relative to human population densities, such as parts of the United States of America (Johnson et al., 1991; Li et al., 2016; Pickett, 1982) and the alpine Andes (Sarmiento et al., 2003). However, without changes in the human valuation of the natural forests, they will continue to be converted to more profitable land uses, especially related to private or corporate interests. For example, in New England, the expansion of secondary forests took place from the mid-1800s until the 1990s following an abandonment of farmland (Foster et al., 1998), but between 1990 and 2005, a total of 133,000 ha of land has be deforested for residential or commercial development (Jeon et al., 2014).

8 | IMPLICATIONS ON THE RELATIONSHIP BETWEEN PEOPLE AND NATURE IN THE ANTHROPOCENE

Human beings, and societies as their collective, have unprecedently altered global ecosystems, leading to degraded ecosystems with reduced levels of ecosystem services (Western, 2001). This phenomenon is one defining characteristic of the Anthropocene (Malhi, 2017). Restoration of degraded forests, especially tropical forests, is a major goal for current global forest management (Lamb et al., 2005). It has been suggested that *'Aligning restoration goals and practices with natural regeneration can achieve the best possible outcome for achieving multiple social and environmental benefits at minimal cost'* (Chazdon & Guariguata, 2016). However, there are few examples available to demonstrate the long-term outcome of natural regeneration because most of the naturally regenerating second-growth forests are relatively young (several decades to one or two centuries) compared to the time needed to reach the old-growth stage.

TABLE 4 The motivation, causes, challenges and examples of forests/ecosystems with low direct human disturbance

Motivation	Causes	Examples	Challenges
Intentional	Religious/Cultural beliefs	Sacred sites, fengshui/geomantic sites	Religious change, economic pressure
	By laws	National parks, National forests, Nature reserve	Law enforcement
Non-intentional	Low development value	Abandoned old-fields, remote (low-accessibility) sites	Changes in land values

We have described a case study in which an ancient forest plantation was protected yet unmanaged, thereby allowing natural regeneration to take place, which resulted in a forest with many characteristics of an old-growth forest, including high biodiversity levels, even aged trees, and a highly variable gap size distribution. The Wanmulin Forest is also characterized by large carbon stocks (both below-ground and above-ground), cultural significance and many ecosystem services of high economic value. Thus, although anthropogenic activity is a main cause for the disappearance and degradation of many old-growth forests around the globe, it is not the only possible outcome. If current second-growth forests are well protected, they have the potential to develop into old forests with characteristics similar to primary old-growth forests and extraordinarily high capacities for providing ecosystem services. However, it takes a long period of time to attain such old-growth forest attributes, most likely more than a few centuries. Thus, it is unwise to interpret the example of the Wanmulin Nature Reserve to claim that forest plantations are ecologically and culturally as valuable as old-growth forests, because it is the multiple centuries of natural succession without human disturbance, not the establishment of forest plantation, that contributes most to the high levels of ecosystem services found in the Wanmulin Nature Reserve.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Neither Dr Zhijie Yang nor Dr Yuesheng is from the Yang family that owned the Wanmulin forest.

AUTHORS' CONTRIBUTIONS

T.-C.L., J.A.H. and Z.-j.Y. wrote the paper; Q.-r.Z., M.-x.Z. and H.-d.Z. collected the paper and took the pictures. All authors contributed to the drafts and gave final approval for the submission.

DATA AVAILABILITY STATEMENT

Sources of all data used in this paper are clearly identified.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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