Buddhist Monasteries Facilitated Landscape Conservation on the Qinghai-Tibetan Plateau

Naixin Cui

Minzu University of China

Tong Wu

Chinese Academy of Sciences

Yi-Chen Wang

National University of Singapore

Huiting Zou

Minzu University of China

Jan Christoph Axmacher

University College London

Weiguo Sang

Minzu University of China

Luo Guo (✉ guoluo@muc.edu.cn)

Minzu University of China

Research Article

Keywords: Buddhist monasteries, Landscape conservation, Land use cover change, Qinghai-Tibetan Plateau

Posted Date: September 28th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-643877/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Context The Sanjiangyuan region of the Qinghai-Tibetan Plateau (also known as the “Three Rivers’ Headwaters”) is the origin of Yellow, Yangtze, and Mekong Rivers and therefore the key water source for hundreds of millions of downstream residents. Protecting this region’s ecosystems is a key priority for sustainable development in China and Asia. An important social dimension of Sanjiangyuan is the long-established and widespread presence of Tibetan Buddhism, particularly as manifested in the large number of monasteries throughout the region. However, the influence of cultural, and specifically religious, factors on environmental change remains largely understudied here.

Objective We focus on two types of spatial associations - point-point and point-area features - to quantitatively investigate the effects of Buddhist monasteries on LUCC in surrounding landscapes.

Methods We conduct a spatially-explicit analysis of Sanjiangyuan for two periods, 1990-2000 and 2010-2015, to identify and quantify the influence of the presence and spatial distributions of Buddhist monasteries on LUCC (or lack thereof, implying landscape conservation) in comparison to village communities that lack monasteries.

Results We found a “clustering effect” in which the spatial aggregation of monasteries being highly correlated with the preservation of natural ecosystems, specifically of grasslands and forests. Within monastery buffer zones with radii between 1 and 10 km, 7.13-9.30% more grassland area and 7.14-7.47% more forest area remained around monasteries compared to villages. This contrast decreased with increasing distance to the monastery/village. Overall built-up areas were also much smaller around monasteries than around villages, while unused land was more commonly transformed to forests and grasslands around monasteries.

Conclusions These findings strongly support the idea that Buddhist culture, as manifested through its physical institutions and communities, are instrumental in achieving desired landscape conservation outcomes.

Introduction

The Qinghai-Tibetan Plateau, which boasts the world’s highest mountains and a rich array of mountain lakes and glaciers, is known as the ‘Third Pole’. It is also called ‘Asia’s Water Tower’ because it forms the upstream water source for nearly 2 billion people across Asia (Qiu 2008; Yao et al. 2012; Zhu et al. 2018). However, major land use/cover changes (LUCC) have occurred in this region in recent decades (Cui and Graf 2009; Hopping et al. 2018; Han et al. 2016; Qiu 2014). LUCC is influenced by many factors that interact across scales, including cultural institutions (Kareiva et al. 1995; Wu 2010). On the Qinghai-Tibetan Plateau, such changes have attracted growing scientific attention, but studies have primarily focused on climate change, urbanization and related government policies (Han et al. 2016; Cheng et al. 2018; Song et al. 2009). The influence of cultural – and particularly religious – factors have been widely

neglected, despite the deeply-embedded influence of Tibetan Buddhism on many aspects of social life and human behavior in this region.

Having arrived over 1400 years ago, Buddhism is the dominant religion of the people living on the Qinghai-Tibetan Plateau, where it is deeply imbricated with social norms and practices. Buddhist monasteries serve as venues for assembly, interaction and instruction, and their grounds and surrounding areas are regarded as sacrosanct. Studies of Tibetan communities in China have found that Buddhist monasteries are often also an important driver of biodiversity and landscape conservation (Li et al. 2014; Shen et al. 2012; Shen et al. 2015; Harris et al. 1991). Central to Buddhism is a worldview that imbues natural formations, from mountains and rivers to the fauna and flora that inhabit them, with a sacredness that encourages environmental protection (James and Cooper 2007; Swearer 2001). A connection between Buddhist belief and ecological conservation has also been reported from field surveys of traditional communities in other parts of the world (Bhagwat and Rutte 2006; Kandari et al. 2014). For instance, respondents have placed higher value on sacred groves and forested temples than on non-sacred greenspaces (David and Marc), with religious beliefs playing a central role in the ecological restoration of those places (Bhagwat et al. 2014).

Previous field investigations of Buddhist monasteries and local villages on the Qinghai-Tibetan Plateau have identified culture as a potentially important factor influencing LUCC in surrounding areas (Yang et al. 2016; Yu et al. 2019), including through the propagation and enforcement of pro-environmental behaviors (Shen et al. 2012). However, there have been few large-scale, spatially explicit studies here that link religious institutions to biodiversity conservation and environmental protection. Understanding these dynamics is nonetheless crucial to ensuring the ecological integrity and human wellbeing at the landscape and regional scale (Wu 2013). Here, we undertake such an analysis by combining field surveys with geospatially-referenced data, to compare LUCC around monastery sites with LUCC around village communities without Buddhist monasteries in their vicinity. The hypothesis that Buddhist monasteries exert a positive effect on the conservation status and development of surrounding landscapes forms the main hypothesis of this research. In Sanjiangyuan, or “Three Rivers Headwaters Region”, of the Qinghai-Tibetan Plateau, where approximately 28% of the population is of Tibetan ethnicity (Fig. 1). Its rich assemblage of forest, grassland and wetland ecosystems highlights its crucial ecological and cultural role in the greater plateau. The region has been called “China’s Water Tower”, since it is the source of three major Asian rivers: Yangtze, Yellow, and Mekong – in whose downstream basins most of China’s population live, and that in the case of the Mekong is also crucially important for large populations in neighboring Asian countries.

In this study, we focus on two types of spatial associations – point-point and point-area features – to quantitatively investigate the effects of Buddhist monasteries on LUCC in surrounding areas. The first spatial association focuses on the respective point patterns of monasteries and villages within counties (villages in this case are defined as lacking monasteries in their direct vicinity, and are thus likely to exert a different effect on the surrounding landscape). The second spatial association is point-area-based and focuses on LUCC around monasteries and villages. Whether Buddhist monasteries can be said to

influence surrounding environmental conditions is determined by whether there is a significant point-area-based spatial association between the village/monastery points and LUCC, and whether this spatial association is influenced by the point-point distribution pattern of said monasteries/villages.

Methods

Study area

The study area (Fig. 1) includes the counties of the four Tibetan Autonomous Prefectures – Yushu, Guoluo, Hainan and Huangnan – along with the Tanggula Township of Geermu Prefecture in the Qinghai province of China. Village location points were obtained from the Qinghai Geographic Information Center, while monastery location points were acquired from our 12 years of field surveys using GPS records of the region. A total of 306 monasteries and 877 villages were included to calculate their point-pattern distributions across the 17 different counties. The study timeframe covers two periods, from 1990–2000 and from 2010–2015 (unfortunately, we had to exclude the time between 2000 and 2010 due to data quality issues for this time interval). The LUCC data were obtained from the Data Center for Resources and Environmental Sciences at the Chinese Academy of Sciences (RESDC) (<http://www.resdc.cn>) and had a spatial resolution of 1000 meters.

Data sources

Our research team, headed by the corresponding author of the paper, conducted a field survey of Tibetan Buddhist monasteries across Qinghai from August 2, 2011 to August 20, 2018, as part of a long-term research initiative of the Central University of Nationalities (Minzu University). Time in the field was concentrated in the months of July and August of each year, and in the month of the Tibetan New Year (February). Over the 7 years, the field survey covered approximately 20,000 kilometers and used GPS devices to record the spatial locations of identified monasteries. The survey data was also guided by, and later corroborated with, official registries of monasteries kept in the official records of local governments.

Spatial datasets were collected as follows: First, we had two vector point datasets covering 306 monasteries and 877 villages. The names and location data were stored in shape files using Arc GIS 10.4.1. Data on village locations in the study area were obtained from the Qinghai Geographic Information Center and data on the monasteries were obtained from field surveys conducted over 12 years (2005–2017), with each location ascertained through GPS. Second, we obtained six vector polygon datasets, with LUCC data covering the years 1990, 1995, 2000, 2010, and 2015 produced and curated by the Chinese Academy of Sciences Resource Environmental Data Center (RESDC) (<http://www.resdc.cn>). This data had a resolution of 1 km by 1 km and an overall accuracy rate greater than 90% (Ning et al. 2018). Land use/cover was classified in accordance with the classification standard system proposed by the Resource and Environment Information Center of the Chinese Academy of Sciences (Liu et al. 2014; Peng et al. 2011). Level-one and level-two land cover types were selected for the study of LUCC. More specifically, for our subsequent analyses, the level-one categories we used were: arable land, construction

land, forestland, grassland, water area, and unused land. ArcMap 10.4.1 was used to conduct the land cover reclassification.

Spatial analysis

We defined an indicator, $P^c_{(rq)}$, to quantify the spatial association between the monastery/village points and surrounding land use/cover polygons within buffer radii of “rq” ($r_1 = 1\text{km}$, $r_2 = 2\text{km}$, ..., $r_{10} = 10\text{km}$) over three periods (1990–1995, 1995–2000, 2010–2015). $P^c_{(rq)}$ values show the average spatial association between monasteries/villages and all LUCC polygons within a buffer zone; they do not, however, quantify any LULCC variation and the contribution of land use/cover types to this association. Therefore, we calculated another indicator, $P^c_{(rq)}$ to quantify this association. Based on this classification data, the spatial relationship between monasteries and the surrounding LUCC polygons was calculated and a Monte Carlo model was used to statistically test the spatial relationship (this indicator only contained 16 counties since there was only one monastery point in one of the counties) (Fig. 2).

First, we conducted a point pattern analysis using Ripley’s K function, a widely-used method that determines the dispersion of points as a function of scale (Arbia et al. 2017; Dale 2000; Dale and Powell 2009). Compared with other point-pattern functions, Ripley’s K function can more accurately analyze the degree of clustering degree over different ranges of distance. Monasteries and villages were considered to be social centers with differing degrees of cultural influence on the surrounding environment. The point distribution patterns of monasteries and villages would exert differing influences on LUCC. Therefore, identifying these distribution patterns is critical to understanding whether and how monasteries and villages influence land use/cover changes across spatiotemporal scales.

There are three types of distribution patterns for control points (monasteries and villages), including random distribution, aggregated distribution, and discrete distribution. The Ripley’s K function value is calculated as follows:

$$\hat{k}(t_q) = A \sum_{\substack{i=1, \\ i \neq j}}^n \sum_{\substack{j=1, \\ j \neq i}}^n \frac{w_{ij} I_{t_q(i,j)}}{n^2}$$

(1)

where A is the area of the study region, d_{ij} is the distance between points i and j , n is the number of control points. $I_t(i, j)$ is an indicator function if the distance of d_{ij} is less than t ($d_{ij} \leq t$), I_t is 1, if not, I_t is 0. “ t_q ” is the radius distance ($t_1 = d_{ij(er)}/10$; $t_2 = 2 t_1$, $t_3 = 3 t_1$, ..., $t_{10} = 10 t_1 = d_{ij(er)}$, and $d_{ij(er)}$ means 25% of the minimum range length of the minimum circumscribed rectangle of i and j . To account for the boundary effect, the numerator is weighted by w_{ij} . If the neighborhood is completely inside the study region, w_{ij} is 1; if not, w_{ij} is defined to be the reciprocal of the ratio of the circumference of the circle falling within the study area.

Lastly, significance tests were obtained using Monte Carlo simulation, following Robinson (1998). First, a set of n random points in the subplot study region was generated according to the number of control points. Then, $\hat{k}(t)$ at t distance scales was calculated. Finally, the above two steps were iterated 999 times and the values were rank-ordered with the empirical values, with the confidence interval set to 99.9%. If the $K(t)$ value for the observed data is larger than the upper confidence envelope (*HiConfEnv*) value, the clustering pattern of control points distribution is significant. Comparatively, if the value for the observed data is lower than the lower confidence envelope (*LowConfEnv*) value, the dispersed pattern of control points is significant. Otherwise, the control points present a random distribution pattern. Considering the set $t_1, t_2, t_3, \dots, t_{10}$, the values over these distances may be clustered or dispersed at certain distance scales but not at others.

To calculate the spatial association between points (monasteries and settlements) and LUCC polygons, we estimated two indicators. The first calculated all LUCC types as a whole, which is indicative of the spatial association between monasteries/villages points and surrounding LUCC. The second concentrates on the primary LUCC types around the points. Finally, significance tests were obtained using Monte Carlo simulation. The first indicator seeks to determine whether the polygons are clustered or dispersed around monasteries/villages at various scales. We treat monasteries and villages as points located in the study area, and LUCC as polygons around the points. For a given point, all surrounding polygons within a given radius are considered as neighbors. If the radius is determined, the circular neighborhood (i.e., buffer zone) will be defined and remain constant across the whole study region to model the spatial relationships between polygons and points. The indicator of spatial association between points and polygons, $P_{(rq)}$, for all LUCC types at given distance r_q is:

$$P_{(r_q)} = \frac{1}{\rho} \frac{\sum_{i=1}^n \sum_{j=1}^m \text{Area}\{(P_i(r_q) \cap T_i \cap T_A) \cap R_j\}}{\sum_{i=1}^n \text{Area}\{P_i(r_q) \cap T_i \cap T_A\}}, (2-1)$$

$$r_q, r_1 = 1\text{km}, r_2 = 2\text{km}, \dots, r_{10} = 10\text{km}$$

$$\rho = \sum_{j=1}^m \text{Area}(R_j) / \text{Area}(T_A), (2-2)$$

where n is the total number of points located in the subplot study region (i.e., monasteries or villages), m is the number of polygons (i.e., polygons of land use/cover changes during the study period), $P_i(r_q)$ indicates the neighborhoods with radius r centered at control point i ; as specified in (2-1), r_q refers to distance r (e.g., with $q=1, 2, 3, \dots, 10; r_1=1\text{km}, r_2=2\text{km}, \dots, r_{10}=10\text{km}$). T_i indicates the Thiessen polygon of the control points i , R_j refers to the LULCC polygons including all types of changes that took place in the study period; each polygon R_j has an attribute describing the type of land use/cover (e.g., from forest to grassland, from construction land to arable land) during the study period; ρ is the density of all types of land use/cover changes, and T_A is the subplot study region. In addition, given the radius ranges $r_1, r_2, r_3, \dots$ and $P_{(r_1)}, P_{(r_2)}, P_{(r_3)}, \dots$, the sign refers to the intersection of several spatial objects, and the function $\text{Area}\{\}$ calculates the area of the space referred to inside the brackets. Consequently, the $P_{(rq)}$ indicator is defined

as the ratio of the LUCC density of the neighborhoods around points to the LUCC density of the subplot study region.

In addition, certain types of LUCC are more pertinent to conservation concerns than others. Therefore, we extended the indicator Eq. 2 to re-specify the spatial association for specific types of land use/cover changes:

$$P^c_{(r_q)} = \frac{1}{\rho_c} \frac{\sum_{i=1}^n \sum_{j=1}^m \text{Area}\{(P_i(r_q) \cap T_i \cap T_A) \cap R^c_j\}}{\sum_{i=1}^n \text{Area}\{(P_i(r_q) \cap T_i \cap T_A)\}}, (3-1)$$

$$r_q, r_1 = 1\text{km}, r_2 = 2\text{km}, \dots, r_{10} = 10\text{km}$$

$$\rho_c = \sum_{j=1}^m \text{Area}(R^c_j) / \text{Area}(T_A), (3-2)$$

where R^c_j refers to polygon j with specific LUCC type c , and ρ_c is the density of LUCC type c in the subplot study region. Compared to Eq. 2, $P_{(r_q)}$ is proportional to the sum of all the $P^c_{(r_q)}$. The $P^c_{(r_q)}$ indicator mainly defines the spatial association between the points (monasteries and villages) and specific types of LUCC, indicating that the cultural influence associated with monasteries strongly influences particular landscape patterns.

Results

Spatial distribution patterns of monasteries and villages

The spatial distribution of monasteries in Sanjiangyuan was uneven, mainly located in the east and south, including the counties of Tongde, Banma, Chengduo, Yushu and Nangqian. Among them, monasteries in Nangqian accounted for the largest number, approximately 23% of the total. There were relatively few monasteries in the central and western areas, such as in the counties of Maduo and Zhiduo, and in Geermu city, which have extremely high altitudes and harsh environmental conditions, even by the standards of the plateau. The spatial patterns of monasteries in 11 counties and villages in 17 counties in the study area met the operating criteria of Ripley's K function. There were two types of spatial patterns for monasteries, namely significant aggregation pattern and random pattern, with no significant discrete distribution pattern. Monasteries in Banma, Zeku, Xinghai, Tongde, Qumalai, Nangqian, Jiuzhi, and Gander counties were randomly distributed within the analytical radius of 10 km, while those in Chengduo and Zadoi counties were clustered within the same range. Yushu showed a significant aggregation distribution within a radius of 8 km. Compared with the spatial patterns of monasteries, those of villages show different distribution characteristics. With the exception of villages in Zhiduo and Golmud, which showed a significant aggregation distribution, villages in the other 15 counties all showed a random distribution pattern within the study area (Fig. 3).

The comparative influences of monastery and village distribution patterns on LUCC

As mentioned above, there are three types of spatial distribution for monasteries: clustered, random distribution, and discrete distribution (Fig. 4). The LUCC polygons for a buffer zone with a radius of 1–10 km also tended to gather together when monasteries were clustered, as shown by the corresponding $P_{(rq)}$ values. This spatial change was especially obvious in Chengdu, Yushu and Zaduo counties (Fig. 5). When the buffer radius was less than or equal to 5 km, the monastery had a particularly significant regulating effect on LUCC. However, this effect was not significant in counties with less than 10 temples. For example, more than 64% of $P_{(rq)}$ values in Dari, Mongol, Maduo, Maqin, and Zhiduo showed a random spatial relationship during the study period, and less than 36% of $P_{(rq)}$ values showed an aggregation relationship, especially during 2010–2015. 90% of the LUCC around monasteries occurred randomly, indicating that the influence of monasteries on surrounding ecological conditions weakened when their numbers were small.

In 1990–1995 and 1995–2000, discrete distribution appeared in buffer zones with radius ≥ 5 km, while for those with radius < 5 km, there was a random distribution. However, from 2010 to 2015, the $P_{(rq)}$ of Gander, Qumalai, and Tongde, within radii of 1–10 km, all showed significant aggregation. Additionally, the spatial relationship between monasteries and LUCC in Jiuzhi, Zeku, and Xinghai was not significant during 1990–2000, but showed a significant aggregation distribution during 2010–2015. Over time, there has been a strong trend of monasteries clustering, especially between 2010 and 2015. In general, the randomly-distributed monastery pattern had no significant effect on LUCC compared with the clustered pattern. While the clustering and distribution of monasteries had a significant influence on surrounding LUCC, the influence decreased with increasing distance between monasteries. The clustering of monasteries can be said to intensify the clustering distribution of LUCC around them.

Compared to monasteries, the effect of village spatial patterns on surrounding LUCC exhibited a mixed association. Unlike with monasteries, there was no regularity in the relationship across spatiotemporal scales. Two counties (Geermu and Zhiduo) had clustered village distributions. Geermu's $P_{(rq)}$ value showed that LUCC within the 10-km buffer zone around villages were discretely distributed throughout the study period, and this significant discrete spatial relationship had a decreasing trend as the radius increased and the study period progressed. Jido's $P_{(rq)}$ value showed the opposite trend, as LUCC within the 10-km buffer zone were significantly clustered, with the clustering decreasing with the expansion of the radius and the passage of time. It is worth noting that the decreases in the degrees of clustering and dispersion indicate an increase in the spatial randomness of $P_{(rq)}$ in both counties. In general, the distribution pattern of the clustered villages did not have a strong and consistent effect on LUCC, in contrast to clustered monasteries (Fig. 5).

Villages in the remaining 15 counties were randomly distributed. LUCC in 6 of the counties (Qumalai, Zeku, Banma, Dazh, Mayu, and Hedo) showed random distribution, and their spatiotemporal trends can be classified into three broad types. The first was characterized by decreasing randomness and increasing clustering of surrounding LUCC polygons (Qumalai and Zeku). The second type showed the opposite trend: over the course of the study period, the randomness of LUCC around villages increased

and the clustering decreased, especially for the period 2010–2015 (Banma, Dazh, Kuji, Mado, and Tongde). Finally, the third type showed clustering LUCC around villages in the 8 remaining counties (Ma'er, Meadow, Yu, Gande, Henan Mongolian, Baoqian, Xinghai, and Yushu) during the period 1990–2000, with the changes in their levels of distributional randomness and discreteness fluctuating with changing buffer radii. In general, LUCC around villages did not evince any regularity across spatiotemporal scales, having more complex spatial relations compared to monasteries.

As can be seen from Fig. 6, LUCC around monasteries during 1990–2015 were mainly clustered, followed by random distribution, and then by discrete distribution. And during 1990–2000, discrete distribution did not appear for radii smaller than 5 km. From 2010 to 2015, the spatial relationship of discrete distribution no longer existed, with clustered distribution being dominant. For villages, the main spatial pattern of surrounding LUCC during 1990–1995 were random distribution, followed by clustered, and discrete distribution. As time went on, the clustered distribution fell, while the discrete distribution gradually increased. Buddhist monasteries had an obvious clustering effect on LUCC, and this effect increased from 2010 to 2015. In terms of villages, although discrete distribution increased, the random distribution of LUCC in the three periods was still the primary pattern. This indicates that villages in general did not have a significant impact on surrounding LUCC. Compared with villages, monasteries had a significant influence on the surrounding landscape.

The effects of monasteries and villages on changes to forests and grasslands

The two most common LUCC around monasteries were forest-to-grassland and grassland-to-forest. Monastery influence on these LUCC types was stronger when points exhibited clustered patterns as opposed to random patterns. Additionally, this monastery-influenced LUCC was more noticeable in the central part of Sanjiangyuan than in other areas, likely due to the significant clustering of monasteries there. However, in other parts of the region, as time progressed, there was also an increasing association between clustered monastery points and forest-to-grassland and grassland-to-forest transitions, suggesting an increase in Buddhist culture-mediated landscape change.

Additionally, the transformation of unused land around monasteries to grassland and forest was much greater than the respective transformations around villages, indicating a pro-environment influence of monasteries. This conclusion is further strengthened by the fact that increases in built-up land were also significantly lower around monasteries than around villages. The transformation of unused land to forest or grassland also increased strongly with increasing distance from villages. Finally, and perhaps most significantly, grasslands and forests surrounding monasteries stayed unconverted at consistently higher proportions compared to patches of these habitats surrounding villages given the same buffer sizes, with the differences between monasteries and villages increasing with the increasing size of the buffer radius (Fig. 7).

Discussion

Our study found that Buddhist monasteries had a strong influence on surrounding LUCC. In particular, the results showed that more LUCC were clustered around monasteries at a given distance than would be expected by chance. This “clustering effect” was more pronounced within a radius of 5 km, meaning that the farther away from a Buddhist monastery, the lower the intensity of its effect on LUCC. Additionally, the greater the clustering of monasteries, the greater the influence on surrounding LUCC. Moreover, when the monasteries were randomly distributed, surrounding LUCC did not present a corresponding random pattern. This showed that since there is a strong effect on LUCC regardless of distributional patterns, it was the Buddhist monasteries themselves, with their distinct cultural characteristics, that was an important driver of landscape change.

We did not find a similarly straightforward association between the distributional patterns of villages and surrounding LUCC. Sanjiangyuan has a diverse composition of communities, and there were likely differences in terms of land use across villages, further reinforced by different policies in different jurisdictions, such as grazing prohibitions, which were limited to some parts of the study areas, as well as different levels of compensation for conservation and restoration efforts (Wang et al. 2015; Wang et al. 2016). The point-area dynamics of villages therefore provide an important contrast to the strong and consistent effects on LUCC found for Buddhist monasteries.

These findings have critical implications for the sustainability of Sanjiangyuan. The region’s forests and grasslands provide many important ecosystem services, including carbon sequestration, water retention and supply, and the provisioning of timber and foodstuffs, the viabilities of which have come under growing threat from local degradation and climate change (Jiang et al. 2016; Wen et al. 2013). Additionally, the region provides habitats for highly endangered species such as the snow leopard (*Panthera uncia*) and Tibetan antelope (*Pantholops hodgsonii*). Sanjiangyuan is also a culturally vital region, where Buddhism has thrived for over a millennium and continues to permeate many aspects of social life (Ji 2012; Yu 2013). Buddhist monasteries are the most concrete manifestations of this cultural dispensation.

Our findings strongly support the hypothesis that Buddhism has a significant effect on the interactions of local communities with their surrounding landscapes. This also consolidates earlier studies that outline the role Buddhist monasteries play in encouraging communal participation in conservation activities from organizing patrols to enforcing a disciplinary regime that included punishments for environmentally deleterious behaviors (Shen et al. 2012). Therefore, Buddhist monasteries are a crucial link between Sanjiangyuan’s social and ecological systems, and the sustainability of local landscapes can be further advanced through the protection and promotion of Buddhist monasteries and their cultural role in this region.

In other parts of the Qinghai-Tibetan Plateau, urban expansion has already encroached upon a significant number of monasteries and their associated communities, causing cultural as well as ecological detriment. This makes the preservation of remaining sites and their surrounding landscapes even more urgent (Zhang et al. 2018). A major and immediate policy implication concerns the establishment of

Sanjiangyuan National Park, which is currently a pilot site of China's emerging country-wide national park system. Once finalized, it will cover our entire study area. At 123,100 km², Sanjiangyuan National Park will be approximately 13.7-times the size of Yellowstone National Park in the United States. Unlike national parks in the US, however, there will still be a long-term and relatively large human population living within its boundaries. Many inhabitants have emigrated or been relocated to the nearby urban centers in recent years, but tens of thousands of pastoralists and villagers are likely to remain for the foreseeable future (Shen and Tan 2012; Wang et al. 2010). We see this as a great chance as well as a challenge, given the long harmonious history of these local residents with their biodiverse environment, as well as the broader mandate of protecting Sanjiangyuan's highly valuable natural resources and landscapes. This mandate should incorporate the protection of its Buddhist monasteries and the promotion of the cultural traditions that they embody.

Conclusion

In our study, we used a spatially-explicit analysis of on the Qinghai-Tibetan Plateau for two time periods – 1990–2000 and 2010–2015 – to quantify the significant influence, in terms of both the presence and spatial distribution, of Buddhist monasteries on LUCC (or lack therefore, implying landscape conservation) as compared to village communities that lack monasteries. We found a “clustering effect”, with the spatial aggregation of monasteries being highly correlated with the preservation of natural ecosystems, specifically of grasslands and forests. Within monastery buffer zones with radii between 1 and 10 km, 7.13–9.30% more grassland area and 7.14–7.47% more forest area remained around monasteries compared to villages. This contrast decreased with increasing distance to the monastery/village. Overall built-up areas were also much smaller around monasteries than around villages, while unused land was more commonly transformed to forests and grasslands around monasteries. These findings strongly support the idea that Buddhist culture – both through its physical institutions and related communal influence – are instrumental in achieving desired ecosystem conservation outcomes.

Declarations

Conflicts of Interest

The authors declare no conflicts of interest.

Funding

This research was funded by the Second Tibetan Plateau Scientific Expedition and Research (STEP) program (2019QZKK0308)

Acknowledgments

We are grateful for the comments of the anonymous reviewers, which greatly improved the quality of this paper.

References

- Anselin L (1995) Local Indicators of Spatial Association—LISA. *Geographical Analysis* 27:93–115. <https://doi.org/10.1111/j.1538-4632.1995.tb00338.x>
- Arbia G, Espa G, Giuliani D, Dickson MM (2017) Effects of missing data and locational errors on spatial concentration measures based on Ripley's K-function. *Spatial Economic Analysis* 12:326–346. <https://doi.org/10.1080/17421772.2017.1297479>
- Boots B, Okabe A (2007) Local statistical spatial analysis: Inventory and prospect. *Int J Geogr Inf Sci* 21:355–375. <https://doi.org/10.1080/13658810601034267>
- Bhagwat SA, Nogué S, Willis KJ (2014) Cultural drivers of reforestation in tropical forest groves of the Western Ghats of India. *Forest Ecology Management* 329:393–400. <https://doi.org/10.1016/j.foreco.2013.11.017>
- Bhagwat SA, Rutte C (2006) Sacred groves: potential for biodiversity management. *Front Ecol Environ* 4:519–524. [https://doi.org/10.1890/1540-9295\(2006\)4\[519:SGPFBM\]2.0.CO;2](https://doi.org/10.1890/1540-9295(2006)4[519:SGPFBM]2.0.CO;2)
- Cheng M, Jin J, Zhang J, Jiang H, Wang R (2018) Effect of climate change on vegetation phenology of different land-cover types on the Tibetan Plateau. *Int J Remote Sens* 39:470–487. <https://doi.org/10.1080/01431161.2017.1387308>
- Cui X, Graf H-F (2009) Recent land cover changes on the Tibetan Plateau: a review. *Clim Change* 94:47–61. <https://doi.org/10.1007/s10584-009-9556-8>
- Dale MRT, (Cambridge University Press (2000) *Spatial pattern analysis in plant ecology*. <https://doi.org/>
- Dale MRT, Powell RD (2009) A new method for characterizing point patterns in plant ecology. *J Veg Sci* 12:597–608. <https://doi.org/10.2307/3236899>
- David G, Marc J (2018) Preferences for attributes of sacred groves and temples along an urbanization gradient in the National Capital Region of India. *Ecol Econ* 152:322–335. <https://doi.org/10.1016/j.ecolecon.2018.06.008>
- Hopping KA, Knapp AK, Dorji T, Klein JA (2018) Warming and land use change concurrently erode ecosystem services in Tibet. *Glob Change Biol* 24:5534–5548. <https://doi.org/10.1111/gcb.14417>
- Han M, Brierley GJ, Cullum C, Li X (Springer, 2016) *Landscape and ecosystem diversity, dynamics and management in the Yellow River Source Zone*, 253–274, <https://doi.org/10.1007/978-3-319-30475-5>

- Harris RBJMR, Development (1991) Conservation prospects for musk deer and other wildlife in southern Qinghai, China. 353–358, [https://doi.org/10.1016/0006-3207\(93\)90773-T](https://doi.org/10.1016/0006-3207(93)90773-T)
- Jenkins T (2002) Chinese traditional thought and practice: lessons for an ecological economics worldview. *Ecol Econ* 40:39–52. [https://doi.org/10.1016/S0921-8009\(01\)00263-4](https://doi.org/10.1016/S0921-8009(01)00263-4)
- James SP, Cooper DE (2007) Buddhism and the environment. *Contemporary Buddhism* **8**, 93–96. The Buddhist Society. <http://www.thebuddhistsociety.org/>. Accessed 25 June 2018
- Ji Z (2012) Chinese Buddhism as a Social Force. *Chinese Sociological Review* **45**, 8 – 2, <https://doi.org/10.2753/CSA2162-0555450201>
- Jiang C, Li D, Wang D, Zhang L (2016) Quantification and assessment of changes in ecosystem service in the Three-River Headwaters Region, China as a result of climate variability and land cover change. *Ecol Ind* 66:199–211. <https://doi.org/10.1016/j.ecolind.2016.01.051>
- Qiu J (2014) Double threat for Tibet. *Nature* 512:240–241. <https://doi.org/10.1038/512240a>
- Kareiva PM, Wennergren U (1995) Connecting landscape patterns to ecosystem and population processes. *Nature* 373:299–302. <https://doi.org/10.1038/373299a0>
- Kandari LS, Bisht VK, Bhardwaj M, Thakur AK (2014) Conservation and management of sacred groves, myths and beliefs of tribal communities: a case study from north-India. *Environmental Systems Research* 3:1–10. <https://doi.org/10.1186/s40068-014-0016-8>
- Li J et al (2014) Role of Tibetan Buddhist monasteries in snow leopard conservation. *Conservation biology* 28:87–94. <https://doi.org/10.1111/cobi.12135>
- Liu Y, Yang R, Long H, Gao J, Wang J (2014) Implications of land-use change in rural China: A case study of Yucheng, Shandong province. *Land Use Policy* 40:111–118. <https://doi.org/10.1016/j.landusepol.2013.03.012>
- Ning J et al (2018) Spatiotemporal patterns and characteristics of land-use change in China during 2010–2015. *J Geog Sci* 28:547–562. <https://doi.org/10.1007/s11442-018-1490-0>
- Peng J, Xu YQ, Cai YL, Xiao HL (2011) The role of policies in land use/cover change since the 1970s in ecologically fragile karst areas of Southwest China: A case study on the Maotiaohe watershed. *Environ Sci Policy* 14:408–418. <https://doi.org/10.1016/j.envsci.2011.03.009>
- Qiu J (2008) China: The third pole. *Nature* 454:393–396. <https://doi.org/10.1038/454393a>
- Robinson A (1998) Randomization, Bootstrap and Monte Carlo Methods in Biology. *Technometrics* 40:84–84. <https://doi.org/10.1080/00401706.1998.10485508>

- Song X et al (2009) Driving forces behind land use and cover change in the Qinghai-Tibetan Plateau: a case study of the source region of the Yellow River, Qinghai Province, China. *Environ Earth Sci* 59:793. <https://doi.org/10.1007/s12665-009-0075-8>
- Shen X et al (2012) Does science replace traditions? Correlates between traditional Tibetan culture and local bird diversity in Southwest China. *Biol Cons* 145:160–170. <https://doi.org/10.1016/j.biocon.2011.10.027>
- Shen X, Tan J (2012) Ecological conservation, cultural preservation, and a bridge between: the journey of Shanshui Conservation Center in the Sanjiangyuan region, Qinghai-Tibetan Plateau, China. *Ecol Soc* 17, <https://doi.org/10.5751/ES-05345-170438>
- Shen X, Sheng L, Wang D, Lu Z (2015) Viable contribution of Tibetan sacred mountains in southwestern China to forest conservation. *Conserv Biol* 29:1518–1526. <https://doi.org/10.1111/cobi.12587>
- Shen X, Lu Z, Li S, Chen N (2012) Tibetan Sacred Sites: Understanding the Traditional Management System and Its Role in Modern Conservation. *Ecol Soc* 17, <https://doi.org/10.5751/ES-04785-170213>
- Swearer DK (2001) Principles and poetry, places and stories: The resources of Buddhist ecology. *Daedalus* 130:225
- Wu J (2013) Landscape sustainability science: ecosystem services and human well-being in changing landscapes. *Landscape Ecol* 28:999–1023. <https://doi.org/10.1007/s10980-013-9894-9>
- Wang P, Lassoie JP, Morreale SJ, Dong S (2015) A critical review of socioeconomic and natural factors in ecological degradation on the Qinghai-Tibetan Plateau, China. *The Rangeland Journal* 37:1–9. <https://doi.org/10.1071/RJ14094>
- Wang P et al (2016) Promise and reality of market-based environmental policy in China: Empirical analyses of the ecological restoration program on the Qinghai-Tibetan Plateau. *Glob Environ Change* 39:35–44. <https://doi.org/10.1016/j.gloenvcha.2016.04.004>
- Wen L et al (2013) Effect of degradation intensity on grassland ecosystem services in the alpine region of Qinghai-Tibetan Plateau, China. *PloS one* 8:e58432–e58432. <https://doi.org/10.1371/journal.pone.0058432>
- Wu J (2010) Landscape of culture and culture of landscape: does landscape ecology need culture? *Landscape Ecol* 25:1147–1150. <https://doi.org/10.1007/s10980-010-9524-8>
- Wang Z, Song K, Hu L (2010) China's Largest Scale Ecological Migration in the Three-River Headwater Region. *AMBIO* 39:443–446. <https://doi.org/10.1007/s13280-010-0054-z>
- Yao T et al (2012) Third Pole Environment (TPE). *Environmental Development* 3:52–64. <https://doi.org/10.1016/j.envdev.2012.04.002>

Yu DS (Routledge, 2013) The spread of Tibetan Buddhism in China: Charisma, money, enlightenment

Yang J, Wang YC, Guo L, Xue D (2015) Patterns and structures of land use change in the Three Rivers Headwaters Region of China. PloS one 10:e0119121. <https://doi.org/10.1371/journal.pone.0119121>

Yu Y, Guo Z, Wang Y-C (2019) Spatial patterns and driving forces of land change in Tibetan-inhabited Three Rivers Headwaters region, China. J Mt Sci 16:207–225, CNKI:SUN:SDKB.0.2019-01-016

Zhu G-F, Gao L-M, Li D-Z (2018) Protect Third Pole's fragile ecosystem. Science 362:1368. <https://doi.org/10.1126/science.aaw0443>

Zhang Y, Zhang H, Sun Z (2018) Effects of Urban Growth on Architectural Heritage: The Case of Buddhist Monasteries in the Qinghai-Tibet Plateau. Sustainability 10:1593. <https://doi.org/10.3390/su10051593>

Figures

Figure 1

The Sanjiangyuan, or “Three Rivers’ Headwaters Region” (TRHR), is located across 17 counties in China’s Qinghai province. Our study incorporated 306 monasteries and 877 villages from across the region. Data sources

Figure 2

The methodological framework used in this study.

Figure 3

Different spatial distribution patterns of monasteries and villages.

Figure 4

Example maps for point-point spatial distributions: A and F show significantly clustering; B, C and E show random distribution; D show discrete dispersion. The brown patches represent observed land use/cover changes within a 10 km radius from 2010 to 2015.

Figure 5

Point-area relationships of five Sanjiangyuan counties.

Figure 6

Differing distribution patterns of monasteries as compared to villages (without monasteries).

Figure 7

Influence of monasteries and villages on the existing grassland (A) and forest (B) habitat patches in their vicinity. The farther the distance from a monastery/village, the greater the contrast in this conservation effect between the two types of communities.