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Proximity and size of protected areas in Asian borderlands enable transboundary conservation

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Asia has over 80% of the Earth's border hotspots for threatened transboundary wildlife, yet only limited research has been done on the distribution of protected areas across international borders in the continent. To address this gap, we conducted a spatial analysis of protected areas across 42 Asian countries. Our study aimed to understand the distribution, proximity, and land-use changes within border protected areas. Two cases were examined, evaluating the spatial relationships at different buffer distances from international borders. Our findings revealed that Asian countries have larger protected areas in borderlands, particularly up to 50 km from borders, as compared to regions further away from the border. Importantly, the median distance between protected areas across international borders is nearly three times shorter than those within the same country. However, the rate of change in natural habitats within protected areas between 2001 and 2019 showed no correlation with their distance from the border. The proximity of protected areas across Asian borders offers opportunities for enhancing connectivity. A larger extent of multi-use protected areas (IUCN1-6+) near borders compared to strict protected areas (IUCN1-4) can facilitate the engagement of communities, which are crucial in transboundary conservation initiatives. Our results can help Asian countries as they work toward their commitments as part of the Kunming–Montreal Global Biodiversity Framework to protect at least 30% of the Earth's surface area by 2030.

KEYWORDS

biodiversity conservation, land-use change, proximity, connectivity, global biodiversity framework

1 Introduction

Conservation measures are often limited by human-made administrative boundaries that do not account for the transboundary ranges of different species (Linnell et al., 2016). More than half of terrestrial species and 21% of threatened species of amphibians, birds, and mammals worldwide have their geographic range spread across more than one international border (Mason et al., 2020). With each country having different wildlife protection laws and regulations, it is challenging to conserve transboundary species (Farhadinia et al., 2020). Additionally, the impact of climate change could alter terrestrial and marine species distributions (Chen et al., 2011; Poloczanska et al., 2013; Lenoir and Svenning, 2015), which may transcend country borders. There is growing evidence from multiple modeling studies which point toward a poleward or higher elevation shift of niches of biodiversity due to changing climate (Parmesan and Yohe, 2003; Root et al., 2003; Hickling et al., 2006; Chen et al., 2011). A lack of habitat connectivity to accommodate the likely shift in a species' niches could lead to lower genetic diversity (Hadly et al., 2004) and thus increase the risk of local extinctions—for example, the effects of climate change could cause more suitable habitat areas of brown bears *Ursus arctos* in South Asian countries to shift toward northern areas like Mongolia and Uzbekistan (Su et al., 2018).

Linking protected areas across international borders could solve some of the challenges of conservation of transboundary species—for example, transboundary conservation areas provide larger habitats and connectivity for species as well as act as buffers against the impact of climate on shifting distribution of species (Hannah, 2010). Through collaborative skills and resources between states and civil societies, transboundary conservation areas can provide multiple benefits to protecting biodiversity and ecosystem services, such as controlling illegal wildlife trade (Yang et al., 2019) and protecting networks of connected areas (Santini et al., 2016). Transboundary conservation areas across the world have demonstrated positive outcomes for conservation efforts. A survey of managers of protected areas which border international boundaries in the Americas revealed that 82% of them believed that transboundary protected areas benefit biodiversity (McCallum et al., 2015). In Africa, even with armed conflicts, the population of mountain gorillas *Gorilla beringei beringei* has been on the rise in the Virunga transboundary conservation area which spreads across Democratic Republic of Congo, Rwanda, and Uganda (Plumptre et al., 2007). In Europe, the Bavarian Forest and Šumava National Parks shared between Germany and the Czech Republic not only provide habitat connectivity for the Eurasian lynx *Lynx lynx* (Magg et al., 2016) but also create opportunities for tourism and collaborative training, research and conservation between these countries (Vasilijević and Pezold, 2011). In Asia, transboundary collaborative initiatives are essential for the conservation of key transboundary species like snow leopards *Panthera uncia* and leopards *Panthera pardus*, which are distributed across 12 and 23 countries, respectively, in continental Asia (Farhadinia et al., 2020; Sultan et al., 2022).

Nonetheless, the spatial configuration of current and potential transboundary conservation areas is not evenly distributed across the world. Although around 82% of the world's border hotspots for threatened transboundary wildlife (species with ranges spanning borders of more than one neighboring country) are present in Asia (Mason et al., 2020), only 22% of the world's transboundary conservation areas are located in Asia (Lysenko et al., 2007). Chowdhury et al. (2022) found that 62% of studies documented anthropogenic threats inside protected areas in South Asia, highlighting that most of these protected areas are small in size. To that extent, South Asian protected areas have been unsuccessful in preventing the loss of habitats within their boundaries (Clark et al., 2013). As a result, Asia fell short in achieving the target of at least 17% of protection by 2020, known as the Aichi Target 11 under the Convention on Biological Diversity (Farhadinia et al., 2022). Furthermore, it has the highest projected rates of habitat loss by 2050 (Molotoks et al., 2018). Transboundary conservation areas present a valuable opportunity for numerous Asian countries to help meet target 3 of the objectives of the Kunming–Montreal Global Biodiversity Framework by 2030, i.e., the conservation of at least 30% of the Earth's surface in areas of significant importance for biodiversity and ecosystem services (CBD, 2022). However, understanding of the spatial configuration, connectivity, and land-use change of Asian borderlands is inadequate to inform this process effectively.

In addition to benefits for biodiversity conservation, transboundary conservation can promote collaboration and peace between bordering countries with a history of military disputes (Barquet et al., 2014). Bordering countries with a moderate level of military disputes are more likely to create transboundary conservation areas than those without any (Barquet et al., 2014). There are several ongoing border disputes between various Asian countries (Komissina and Kurtov, 2003), and transboundary conservation has the potential to reduce such inter-state tensions and bolster cooperation (Barquet et al., 2014; Bierman, 2020). Conservation can even serve as a diplomatic tool to initiate the resolution of disputes between states, and there has been an increasing interest in the designation of peace parks to promote peace between conflicting countries (Ali, 2007; Marton-Lafevre, 2007; Mackelworth et al., 2012; Maheshwari, 2020).

With this important context in mind, this study aimed to improve understanding of the distribution, proximity, and land-use change of protected areas along the international borders of Asian countries. We defined proximity of protected areas, in this context, as the shortest distance between two adjacent protected areas. Through a spatial analysis of protected areas, we addressed three research questions:

1) How does the relationship between the extent of protected areas and their distance from borders vary among different categories of protected areas?
2) How does the proximity of protected areas change across international borders compared to those within individual countries?

3) How does the rate of habitat loss, specifically the conversion of natural habitats within protected areas, correlate with their distance from borders?

2 Materials and methods

We addressed the research questions with respect to all Asian countries, including those in the Caucasus (see Supplementary Figure S3 for the list of studied countries). Island countries that do not share a terrestrial border with another country were excluded. North Korea was also excluded due to lack of data on the distribution of protected areas there.

The terrestrial protected areas data were obtained from the World Database on Protected Areas (WDPA) on 5 April 2020 (UNEP-WCMC and IUCN, 2020). We used the 2017 version of the WDPA data for China because the 2020 dataset has multiple missing protected areas. We acknowledge that some protected areas in China may have been updated since 2017, and that has not been accounted for in this study. Protected areas with status "proposed" were included in our study to explore the potential future opportunities for transboundary conservation. Protected areas designated as UNESCO MAB Biosphere Reserves were also included. Additionally, we included protected areas marked as "not reported" to prioritize potential errors of inclusion rather than errors of exclusion in the dataset. All point data (~8.5% of the total number of protected areas) were removed as the polygon of protected area boundaries was required for analyses.

We considered two cases of protected areas following the International Union for Conservation of Nature (IUCN) guidelines: (1) strict protected areas (IUCN1-4), which are primarily aimed at protection of land, and (2) multi-use protected areas (IUCN1-6+), including protected areas in all IUCN categories which are multi-use protected areas and not exclusively for land protection (UNEP-WCMC and IUCN, 2020). Protected areas which had overlapping boundaries were merged using the dissolve function on ArcMap to avoid counting them multiple times. All the spatial analyses were carried out in ArcGIS ArcMap 10.8 (ESRI, 2020) in World Cylindrical Equal Area projection.

2.1 Protected area extent in borderlands

Following Thornton et al. (2020), we created 10 buffer classes of 25 km each (up to 250 km) inside the border of each country (Figure 1). This large distance from the border was selected to accommodate the large size of several Asian countries. For Asian countries with coastlines, we supplemented this step by intersecting the buffers with the country boundary to create 10 25-km-wide buffer regions along the shared borders. Islands and areas with no terrestrial connectivity were excluded from the analysis. Then, the strict (IUCN1-4) and multi-use protected areas (IUCN1-6+) were separately clipped to the different buffer classes of each country.

To evaluate the proportion of each buffer as protected area in relation to the buffer distance, we fitted beta regression with random effect using the package "glmmTMB" (Magnusson et al., 2017) with the link function logit in RStudio 2021.09.0 + 351 "Ghost Orchid" Release (R Core Team, 2021). The beta regression is useful when modeling continuous proportional response variables that assume values in the open standard unit interval between 0 and 1 (Douma and Weedon, 2019). We also fitted an intercept model without the effect of buffer distance. The country was included as a random effect. We fitted two sets of models for two cases of protected areas, i.e., strict (IUCN1-4) and multi-use protected areas (IUCN1-6+). We used likelihood-ratio tests to compare the intercept-only model with the model containing buffer as predictor using "lmtest" package (Zeileis and Hothorn, 2002). We finally employed the "DHARMa" package (Hartig, 2022) to assess the assumption of homogeneity of residuals and to identify outliers and dispersion patterns.

We then calculated the coefficient of determination (R^2) using the package "performance" (Lüdecke et al., 2020) to demonstrate the proportion of variation explained by the top model. We finally applied *post-hoc* Tukey's test to identify pairwise differences in proportions of protected areas, based on the top model using "lsmeans" package (Lenth, 2016). We also ran a Wilcoxon signed-rank test to compare the proportion of protected areas across buffers for strict (IUCN1-4) and multi-use protected areas (IUCN1-6+).

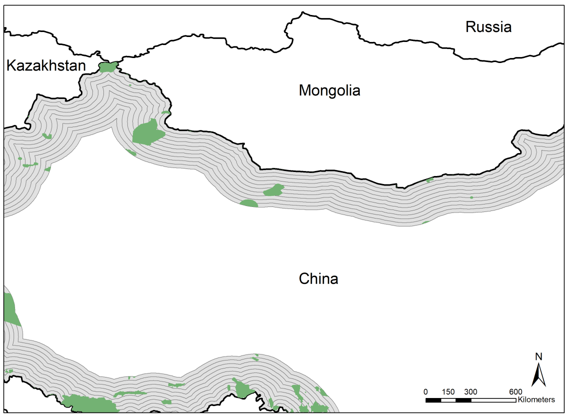

FIGURE 1
An example of buffer analysis for China. The gray color indicates the 25-km-long buffer distance from the border, which extends up to 250 km from the border. The green color indicates the protected areas which have been clipped to the buffer classes.

2.2 Protected area proximity in borderlands

We created three buffer classes for each Asian country: (1) country border buffer: 0–100 km internal buffer from the border of the country, (2) internal buffer: 100–200 km internal buffer from the border of the country, and (3) external buffer: 0–100 km external buffer from the border of the country covering all the adjacent countries with shared borders (Supplementary Figure S1). For smaller countries, 25- and 50-km buffer classes were created. This distance was determined based on the number of buffer classes possible for each country in the previous step. The multi-use protected areas were then clipped to these buffer regions for each country, and protected areas with an area of less than 10 km^2 were excluded.

To measure the proximity of protected areas internally (i.e., within a country) and externally (i.e., outside a country), we calculated the straight-line distance of each protected area in the country border buffer to the closest protected area in the adjacent buffer (Supplementary Figure S1). We used the proximity tool Near on ArcMap for this analysis. We acknowledge that connectivity would not always be possible in a straight line due to geographic and human-made barriers. The internal and external proximity measures were compared using non-parametric Wilcoxon signed-rank test for each country.

2.3 Land-use change in borderlands

We obtained MODIS land cover maps (MCD12Q1-LC1) from 2001 and 2019 for the study area using MODIStsp package in R (Busetto and Ranghetti, 2016). For both 2001 and 2019, we reclassified forests, grasslands, savannas, and shrublands (i.e., classes 1–10) and barren or sparsely vegetated (i.e., class 16) as natural habitat. These layers were masked to the multi-use protected area layer generated in the previous step using extract raster by mask tool on ArcMap. This raster was then converted to polygon and clipped to the multi-use protected areas in each of the 10 25-km-long buffer classes (Supplementary Figure S2). Finally, the area of natural habitat within the protected areas in each buffer class was calculated for each country.

We then fitted generalized linear mixed models (GLMM) with a Poisson error distribution using the package "lme4" (Bates et al., 2015) to understand the change in the proportion of natural habitat within protected areas between 2001 and 2019 in relation to the buffer size. We also fitted an intercept model without the effect of buffer size. We used likelihood ratio tests to compare the intercept-only model with the model containing buffer as predictor. We used country as a random effect. We finally calculated the R^2 for the GLMM model to demonstrate the proportion of variation explained by the model using the package "performance" (Lüdecke et al., 2020).

3 Results

3.1 Protected area extent in borderlands

For both cases of protected areas, i.e., strict protected areas (IUCN1-4) and multi-use protected areas (IUCN1-6+), the models with buffer as predictor outperformed the intercept-only models (X^2_{Strict} = 54.07, df = 1, P < 0.01 and $X^2_{Multi\text{-}use}$ = 40.83, df = 1, P < 0.0). However, the marginal R^2 (fixed effects only) was 0.10 for both cases, suggesting that fixed effect (buffer size) accounted for a small variance in the association, while the random effect (country) represented a larger variance. Accordingly, the proportion of buffer as protected areas was negatively associated with the buffer size for strict protected areas (IUCN1-4; β = -0.005 ± SD 0.001; t = -7.75, P <0.01). The same declining pattern was also seen for multi-use protected areas (IUCN1-6+, β = -0.004 ± SD 0.001; t = -6.55, P < 0.01; Figure 2).

Both cases of protected areas, i.e., strict (IUCN1-4) and multi-use protected areas (IUCN1-6+), showed a declining pattern of the protected area extent until 125 km from the border (Figures 2A, C). However, the proportion of buffer as protected area had different patterns between the two protected area cases. In strict protected areas (IUCN1-4), the declining trend was observed up to 125 km from the border, while the same pattern was seen for 50-km distance from the borders in multi-use protected areas (IUCN1-6+; Figures 2B, D).

Importantly, the proportion of buffer as protected area was larger closer to borders (25 and 50 km) than to farther buffers (>75 km) in the multi-use protected areas compared to strict protected areas (Tukey's test, P < 0.05). Similarly, the proportion of buffer as protected area was larger in the case of multi-use compared to strict protected area case in all buffer classes (Wilcoxon signed-ranked test, P < 0.05; Figure 2), confirming the larger extent of multi-use protected areas compared to strict protected areas within each buffer, particularly those closer to the borders (Figure 2).

There was a high variation in the protected area extent and proportion of buffer as protected area between Asian countries. However, the protected area extent showed a general negative trend in relation to the distance from borders for multi-use protected areas (IUCN1-6+) in 92.9% (n = 39) of Asian countries (Supplementary Figure S3). Similarly, there was a negative pattern for the proportion of buffer as protected area in relation to the buffer sizes for multi-use protected areas (IUCN1-6+) in 76.2% (n = 32) of Asian countries (Supplementary Figure S4). Nepal, India, and Thailand had a larger protected area extent and higher proportion of buffer as protected areas near borders (Supplementary Figures S3, S4).

3.2 Protected area proximity in borderlands

The median nearest neighbor distance of protected areas was 22.5, IQR, 0–67.9 km externally, while it was significantly larger internally (67.1, IQR: 26.1–114.5 km; Wilcoxon signed-rank test; P < 0.05; Figure 3). In 50% (n = 21) of Asian countries, the external distance to protected areas was shorter than their internal distances (Wilcoxon signed-rank test; P < 0.05, Figure 4). Only the UAE and Tajikistan had a larger external distance to protected areas compared to their internal proximities (Wilcoxon signed-rank test; protected areas P < 0.05). In 11 countries, including Bangladesh, Bhutan, Iraq, Israel, Kyrgyzstan, Kuwait, Lebanon, Pakistan, Saudi Arabia, Timor-Leste, and Turkey, there was no evidence of different proximity between protected areas internally or externally (Wilcoxon signed-rank test; P > 0.05; Supplementary Table S1).

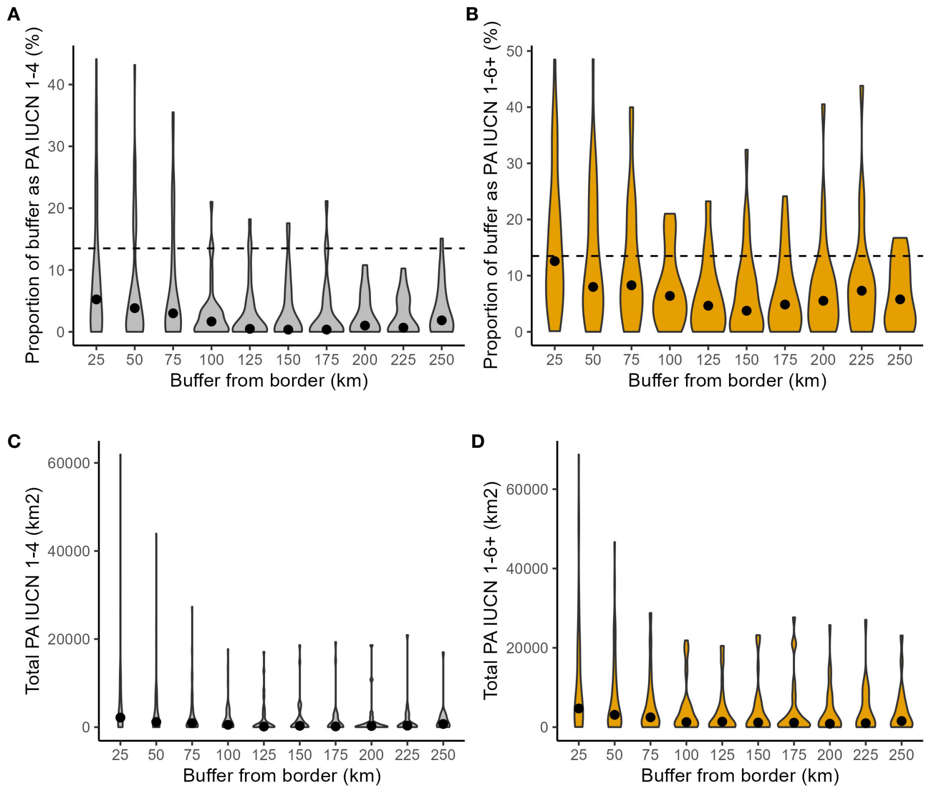

FIGURE 2
Proportion of protected area within each buffer distance class (median and 95% CI) for **(A)** strict protected areas (i.e., IUCN1-4) and **(B)** and multi-use protected areas (i.e., IUCN1-6+). Amount of protected area (km^2) within each buffer distance class (median and 95% CI) for **(C)** IUCN1-4 and **(D)** IUCN1-6+. The black dots represent the median. The dashed lines on **(A)** and **(B)** are the current percentage of protected area coverage across Asia by the end of 2020, equal to 13.5% which was calculated based on data obtained from www.protectedplanet.net.

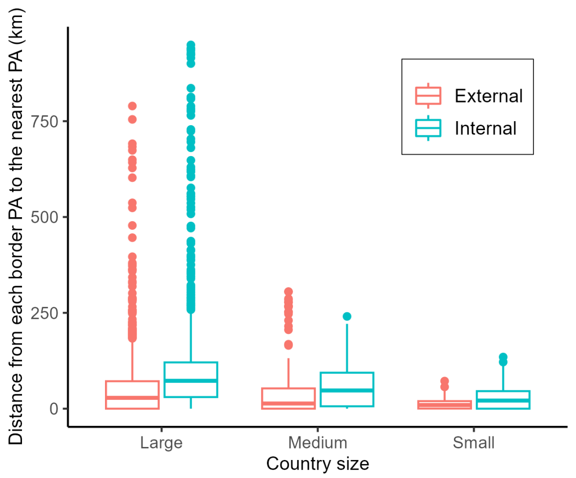

FIGURE 3
Distance from each protected area in the border buffer of each country to the nearest multi-use protected area (IUCN1-6+) within that country (i.e., internal) or the nearest protected area across border in the neighboring country (i.e., external) for 42 Asian countries. The country size corresponds to the maximum size of buffer fitted within each country (0–25 km = small, 25–50 km = medium, and >100 km = large). The boxplots show the median within the interquartile range.

3.3 Land-use change in borderlands

The model with buffer as predictor outperformed the intercept-only model ($X^2 = 76.29$, df = 9, $P < 0.01$; $R^2 = 0.38$). Nonetheless, there was no evidence for the change in proportion of natural habitat within protected areas from 2001 to 2019 in relation to buffer sizes ($F_{9,\ 215} = 1.62$, $P = 0.11$; Figure 5). Kuwait, Oman, and Qatar did not have any significant changes in the proportion of natural habitat within protected areas, whereas Cambodia, India, Indonesia, Pakistan, and Tajikistan had an overall loss in the proportion of natural habitat within protected areas, with this decrease becoming more pronounced as one moves farther from the country borders. In contrast, Azerbaijan, Bangladesh, and Bhutan had an overall gain in the proportion of natural habitat within protected areas.

Focusing on areas near the border (primarily within the 25-km buffer class), Asian countries showed variable responses in the proportion of natural habitat in protected areas (Supplementary Figure S5). In total, 47.6% (n = 24) Asian countries experienced a loss in proportion of natural habitat in protected areas, while nine countries, i.e., Azerbaijan, Bhutan, Brunei, Georgia, Jordon, Kazakhstan, Russia, South Korea, and Thailand demonstrated an increase in the proportion of natural habitat in protected areas within 25 km from the borders.

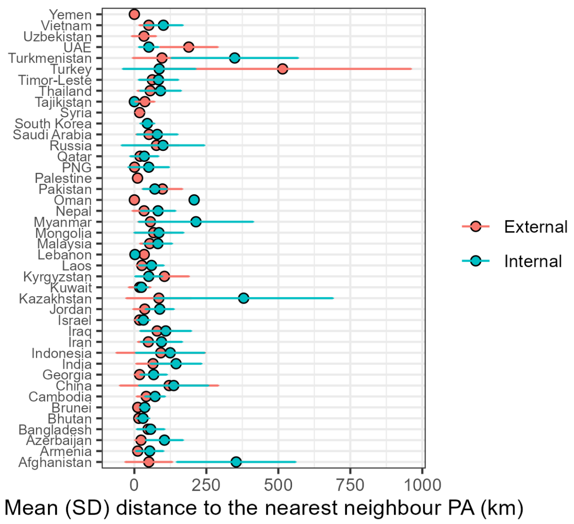

FIGURE 4
Country-wise nearest-neighbor distance between protected areas within the country (i.e., internal) *versus* those across borders (i.e., external) for Asian countries. The dots with error bars represent mean and SD, respectively.

4 Discussion

Our study demonstrates that Asian countries have larger protected areas near country borders as compared to regions away from the border. Additionally, the median distance between protected areas across international borders is almost three times shorter compared to the distance between protected areas within the country. This provides potential opportunities for connecting these protected areas across the borders and establishing transboundary conservation areas. Given that Asia was falling short of reaching the Aichi Target 11 to expand protected areas to at least 17% by 2020 (Farhadinia et al., 2022) with low connectivity between protected areas (3.2%) in comparison with the global mean (9.7%; Ward et al., 2020), transboundary conservation areas could potentially enable many Asian countries to supplement their spatial commitments as part of the Kunming–Montreal Global Biodiversity Framework's target 3 to set to protect at least 30% of the planet by 2030 (CBD, 2022).

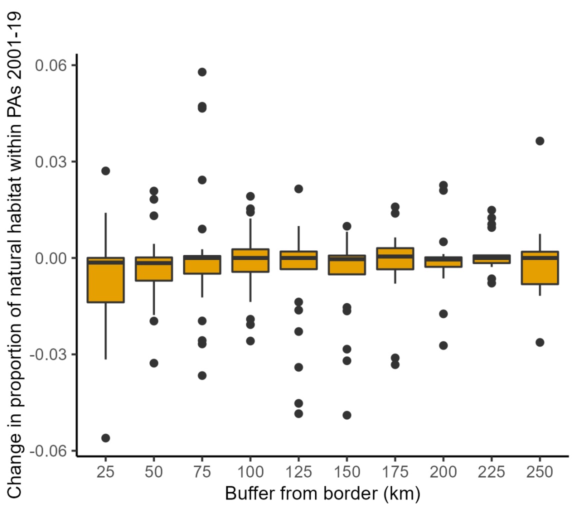

FIGURE 5
The rate of change in the proportion of natural habitats within protected areas in different buffer classes from 2001 to 2019. Positive and negative values indicate an increase or decrease in natural habitat over time, respectively. The boxplots represent the median within the interquartile range.

4.1 Protected area extent in borderlands

Our analyses show that the extent and proportion of buffer as protected area are larger near the borders of Asian countries than those away from the borderlands. The same pattern was also noted for the relationship between protected areas and borderlands across the Americas (Thornton et al., 2020), showing that the occurrence of more extensive lands under protection near international borders can be seen in several parts of the globe.

This pattern can be explained in two ways. First, most protected areas in the world are found in high-altitude regions and away from human habitation (Joppa and Pfaff, 2009). Various high-altitude mountain ranges, such as the Himalayas, Tien Shan, Altay, Ural, Kopet Dag, and Lesser Caucasus, form sections of natural borders for some countries which could further explain why more protected areas are found closer to borders. Second, areas of high development activities are located away from political boundaries, and the human impacts on these regions are small (Agrawal, 2000).

Understanding the geographic distribution patterns of protected areas alone does not provide a comprehensive view of the biodiversity within these areas. To prioritize and strengthen the case for establishing border protected areas as transboundary conservation areas, it is essential to assess further the status of biodiversity within them and compare it with that within internal protected areas (Penagos Gaviria et al., 2022). This will help us understand whether the biodiversity found within border protected areas is a good representation of the country-level biodiversity, thereby strengthening the rationale for implementing more robust conservation measures, including the establishment of transboundary conservation initiatives where necessary.

Transboundary conservation areas are criticized on the grounds that they often do not have enough involvement of local communities (Brosius and Russell, 2003; Metcalfe, 2003). Nonetheless, our modeling shows that the larger extent and proportion of buffer as protected area, which are multi-use protected areas (IUCN1-6+), occur near borders than distant landscapes. Therefore, multi-use protected areas can provide more opportunities for transboundary conservation than those designated solely for biodiversity conservation (strict protected areas, i.e., IUCN 1-4 categories), while they are also more likely to account for local engagement. Nonetheless, transboundary conservation areas need to be assessed on a case by case basis, taking into consideration the status of the environment and various socioeconomic factors (Portman and Teff-Seker, 2017) to avoid creating ineffectively managed "paper parks" (Rife et al., 2013). Similarly, law enforcement units are generally understaffed across most Asian countries (Farhadinia et al., 2023); thus, enhancing transboundary collaboration among countries could bolster the efficiency of efforts through knowledge sharing, resource pooling, and coordinated efforts (Vasilijević et al., 2015).

4.2 Protected area proximity in borderlands

The spatial configuration of protected areas along Asia's international borders reveals that they have a higher proximity to neighboring country's protected areas (i.e., externally) than those located within the same country (i.e., internally). Therefore, Asian borderlands provide potential opportunities to create large transboundary conservation landscapes, given the presence of large-sized protected areas near borders and their proximity to other protected areas across borders. Large transboundary conservation landscapes can also support the population persistence and range recovery of many wide-ranging large carnivores which depend on borderlands in Asia (Thapa et al., 2017; Farhadinia et al., 2020; Li et al., 2020).

It is noteworthy that Penagos Gaviria et al. (2022) found that the structural connectivity of protected areas near borders in Asia is greater than that between those located further inside the country. This finding, combined with our observation of closer proximity between protected areas across the border, suggests that there is considerable potential for establishing ecological corridors and promoting transboundary conservation efforts. Several studies using various connectivity metrics have found that the protected area structural connectivity in Asia is low in comparison with the global mean (Saura et al., 2018; Ward et al., 2020; Penagos Gaviria et al., 2022). Establishment of transboundary conservation areas could improve this deficiency in the current connectivity of protected areas in Asian countries.

To effectively address transboundary conservation in Asia, it is a priority for future studies to investigate further the functional connectivity between protected areas across borders, particularly for species with transboundary ranges. This targeted research (such as those of Kamath et al. (2023) carried out for Africa) will provide important insights in the quest to identify the specific protected areas that require attention and conservation interventions.

4.3 Land-use change in borderlands

The overall change in proportion of natural habitat in protected areas close to border regions remained relatively stable between 2001 and 2019, irrespective of the distance from border. This pattern aligns with findings from the Americas by Thornton et al. (2020). Therefore, the lower level of natural habitat loss in protected areas near borders suggests that expanding transboundary conservation landscapes can support the efforts of many Asian countries to ensure that their natural habitats remain less affected by anthropogenic activities, at least along borderlands.

Importantly, low levels of habitat loss were also found in protected areas, particularly within 25 km from borders in 20 Asian countries. We acknowledge that our study may overlook fine-scale changes occurring to natural habitats at the level of individual protected areas and may be insensitive to the degradation of natural habitats, such as transitions from dense forest to moderately dense/secondary forest. Additionally, our study does not capture habitat-specific alterations such as the conversion of forests into shrublands or afforestation of grasslands, which can pose a significant threat to biodiversity and ecosystem services (Veldman et al., 2015). To gain a more nuanced understanding, future research should analyze these changes in finer detail, including on-ground assessments, considering the baseline habitat conditions within the local context of each protected area.

5 Conclusion

Our findings suggest that the larger and closer protected areas along borderlands in Asian countries, which were generally associated with low levels of natural habitat loss, provide an opportunity to establish transboundary conservation landscapes. The spatial configuration of multi-use protected areas (IUCN1-6+) around borderlands can facilitate the engagement of local communities in the development and governance of transboundary conservation landscapes in Asia. Therefore, they can serve as a combination of protected and conserved areas IUCN1-4) and "other effective area-based conservation measures" (OECMs; IUCN1-6+). The latter, defined as "geographically defined areas other than PAs, governed to achieve positive biodiversity conservation outcomes with associated ecosystem functions and services as well as cultural, spiritual, socio–economic, and other locally relevant values" (CBD, 2018), can support conservation outcomes outside the protected area network while delivering socioeconomic benefits to local communities.

However, the concerns associated with national sovereignty and related to national security, in addition to the impact of border fences, are significant challenges to the adoption of transboundary conservation in many Asian countries (Wolmer, 2003; Linnell et al., 2016). Construction of border fences may impede the movement of those terrestrial species characterized by high mobility (Karlstetter and Mallon, 2014; Farhadinia et al., 2020). To address these challenges, Linnel et al. (2016) offered recommendations for mitigating negative impacts of border fencing, such as raising awareness about the importance of border regions for wildlife, setting up wildlife-friendly fences, adjusting conservation approaches to align with the political situation of the country, and conducting more studies on how border fences affect biodiversity.

Target 3 of the Kunming–Montreal Global Biodiversity Framework encourages countries to conserve ≥30% of their lands through effectively and equitably managed, ecologically representative, and well-connected systems of protected areas and other effective area-based conservation measures (OECM) (CBD, 2022). On the basis of our analyses, we argue that expanding transboundary conservation and collaboration can support many Asian countries in the quest to achieve this target.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

VK: Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Project administration, Funding acquisition. IO: Writing - Review & Editing. DM: Writing - Review & Editing. MF: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing - Review & Editing, Visualization, Supervision, Project administration, Funding acquisition. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2023.1237109/full#supplementary-material

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