Comparing traditional and automated conservation assessments for Himalayan species of *Buddleja*

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Abstract To compare the benefits and drawbacks of traditional and automated conservation assessments, we used a field-based study and automated conservation assessments using *GeoCAT*, *red* and *ConR* to assess four species of *Buddleja* (Scrophulariaceae), a cosmopolitan genus of flowering plants. *Buddleja colvilei*, *Buddleja sessilifolia*, *Buddleja delavayi* and *Buddleja yunnanensis* are endemic to the Himalayan region. They have not yet been assessed for the IUCN Red List of Threatened Species but are facing elevated risks of extinction because of various anthropogenic and environmental pressures. *Buddleja sessilifolia* and *B. delavayi* are listed as Plant Species with Extremely Small Populations in Yunnan, China, where they are known to be threatened. Although automated assessments evaluated *B. delavayi* and *B. yunnanensis* as Endangered and *B. sessilifolia* and *B. colvilei* as Vulnerable, our field studies indicated a different categorization for three of the species: *B. delavayi* and *B. yunnanensis* as Critically Endangered and *B. sessilifolia* as Endangered. Our findings indicate that the accuracy and reliability of assessment methods can differ and that field surveys remain important for conservation assessments. We recommend an integrated approach addressing these limitations, to safeguard the future of other species endemic to the Himalayan region.

Keywords Automated conservation assessment, *Buddleja*, conservation, Himalaya, IUCN Red List, Plant Species with Extremely Small Populations, PSESP, threats

Introduction

The Himalayan region is a globally important biodiversity hotspot (Myers et al., 2000), but its ecology is fragile (Valdiya, 1984, 2016). The area is prone to natural disasters (Pathak, 2016) such as earthquakes (Dal Zilio et al., 2021) and subsequent landslides that can lead to habitat and vegetation clearance. In addition, human population growth and anthropogenic activities are now affecting not only Himalayan ecology and vegetation but also the geomorphology (BBC News, 2023). The melting of Himalayan glaciers (Xu et al., 2009) and bursting of glacial lakes (Veh et al., 2020) have put further pressure on the region's ecosystems, increasing the need to study the species and ecology of this area.

The genus *Buddleja* (Scrophulariaceae) encompasses c. 90 species and has a wide distribution across the tropical, subtropical and warm-temperate regions of Africa, Asia and the Americas (Li & Leeuwenberg, 1996; Chau, 2017; Norman, 2000). The Sino-Himalayan region in Southeast Asia is a centre of diversity for the genus and harbours 25 of the 27 Asian *Buddleja* species (excluding only *Buddleja curviflora* and *Buddleja japonica*; Wu et al., 2010). Many *Buddleja* species are notable for their aesthetic appeal (Chen et al., 2012, 2014; Zhang, 2020), medicinal properties (Backhouse et al., 2008; Khan et al., 2019; Yang et al., 2023b), cultural significance (Namsa et al., 2011; Li et al., 2020) and ecological role (Gong et al., 2015; Verbeke et al., 2023).

During several years of fieldwork it became evident to us that some Himalayan *Buddleja* species, notably *Buddleja colvilei*, *Buddleja sessilifolia*, *Buddleja delavayi* and *Buddleja yunnanensis*, are facing threats from anthropogenic disturbance and environmental pressures. These species share distinctive features such as a limited distribution range, a preference for high-altitude habitats and a susceptibility to human interference, all of which make them particularly vulnerable to changes in their environment. The four species have not yet been assessed for the IUCN Red List of Threatened Species (IUCN, 2023a). To date, *Buddleja bhutanica* is the only Asian species of *Buddleja* that has been assessed, and is categorized as Vulnerable (Bhutan Endemic Flowering Plants Workshop, 2017). *Buddleja colvilei, B. delavayi* and *B. yunnanensis* are included on the Threatened Species List of China's Higher Plants (Qin et al., 2017). *Buddleja sessilifolia* and *B. delavayi* are included on the List of Yunnan Protected Plant Species with Extremely Small Populations (Sun, 2021) because of their reduced populations, restricted habitats, the presence of severe human disturbance and the heightened risk of extinction (Ren et al., 2012; Ma et al., 2013). Further evaluation is required to assess these four species for inclusion on the IUCN Red List.

Buddleja colvilei Hook.f. & Thomson is a shrub or small tree characterized by its attractive foliage and flowers, and was referred to as 'the handsomest of all Himalayan shrubs' by Hooker in 1849 (Stuart, 2006). It is endemic to the eastern Himalayas of Nepal, India (Sikkim), Bhutan and China (Tibet) at 1,600–4,200 m elevation.

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Buddleja sessilifolia B.S. Sun ex S.Y. Pao is a perennial shrub with sessile leaves that usually grows in dense clusters beneath Himalayan hemlock *Tsuga dumosa* forests or at the edges of humid valleys. The species was described in 1983 as being conspecific with *B. colvilei*, a plant distributed throughout the Gaoligong Mountains at 2,600–3,200 m (Ge et al., 2018). In 2018, *B. sessilifolia* was delineated as a distinct species (Ge et al., 2018), suggesting that the disparity in the morphological and molecular characters of these two species was caused by differences in ploidy levels or speciation processes during the uplift of the Himalayas (Yang et al., 2023a).

Buddleja delavayi Gagnepain is a perennial shrub characterized by two distinct colour polymorphisms that exhibit purple or white flowers (Chen et al., 2015). This species is distributed in sparse montane forests and moist broadleaved forests on hillsides in Dali, Yunnan, at 2,000–3,000 m.

Buddleja yunnanensis Gagnepain, which is a narrowly endemic species, is limited to Pu'er and Xishuangbanna, Yunnan, China. It is distributed on the edges of shrub forests on mountains or hillsides at 1,000–2,500 m (Li & Leeuwenberg, 1996).

Data-driven analyses can illuminate the interplay of variables that affect a species' conservation status, but a lack of reliable data, obsolete information and inconsistencies can limit the accuracy and reliability of conservation assessments (Zizka et al., 2021). Automated assessments have the potential to mitigate these issues by creating standardized evaluations or by prioritizing species for reassessment (Cazalis et al., 2022; de Caetano et al., 2022). Two approaches that have been used for automated conservation assessment are: (1) the criteria-explicit approach, which uses automatic calculation of the IUCN Red List parameters from distribution data, using tools such as *GeoCAT* and *rCAT* (Bachman et al., 2011) or packages such as *red* (Cardoso, 2017), *ConR* (Dauby et al., 2017) and *Rapid Least Concern* (Bachman et al., 2020) in *R* (R Core Team, 2023), and (2) the category-predictive approach, which employs machine learning such as random forests (Pelletier et al., 2018) or neural networks (Zizka et al., 2022) and generalized linear models (Böhm et al., 2016). Here we assess the conservation status of the four *Buddleja* species (Plate 1) as a case study, comparing traditional assessments based on field studies with automated assessments.

Methods

Our study area encompasses the trans-Himalayan region, spanning the eastern Himalayas to south-western China (Fig. 1), including eastern Nepal and western China (Yunnan and Tibet). We first collected species occurrence records from the *Flora of China* (Li & Leeuwenberg, 1996), Herbarium KUN at the Kunming Institute of Botany, Chinese Academy of Sciences, the Chinese Virtual Herbarium (2023), GBIF (2023) and iPlant (2023). Using the distribution information from these sources we selected 12 locations that together represent almost all known sites of the four species. We conducted field studies over 13 years (2010–2022) to obtain comprehensive data on the four species, following the recommendations for field investigations of Plant Species with Extremely Small Populations (Yang & Sun, 2017; Yang et al., 2020). Our field study did not include the populations of *B. colvilei* in Bhutan and India, mainly because of geographical barriers and feasibility constraints.

PLATE 1 (a) *Buddleja colvilei*, (b) *Buddleja sessilifolia*, (c) *Buddleja delavayi*, (d) *Buddleja yunnanensis*, (e) mature *B. colvilei* cut down in Ilam, Nepal, (f) loss of habitat of *B. sessilifolia* caused by debris flow and mudslides in the Gaoligong Mountains, Yunnan, China, (g) *B. sessilifolia* plantlets in Kunming Botanical Garden, and (h) living collection of *B. delavayi* in Kunming Botanical Garden. Photos: Fengmao Yang (a,c); Jia Ge (b,d–h).

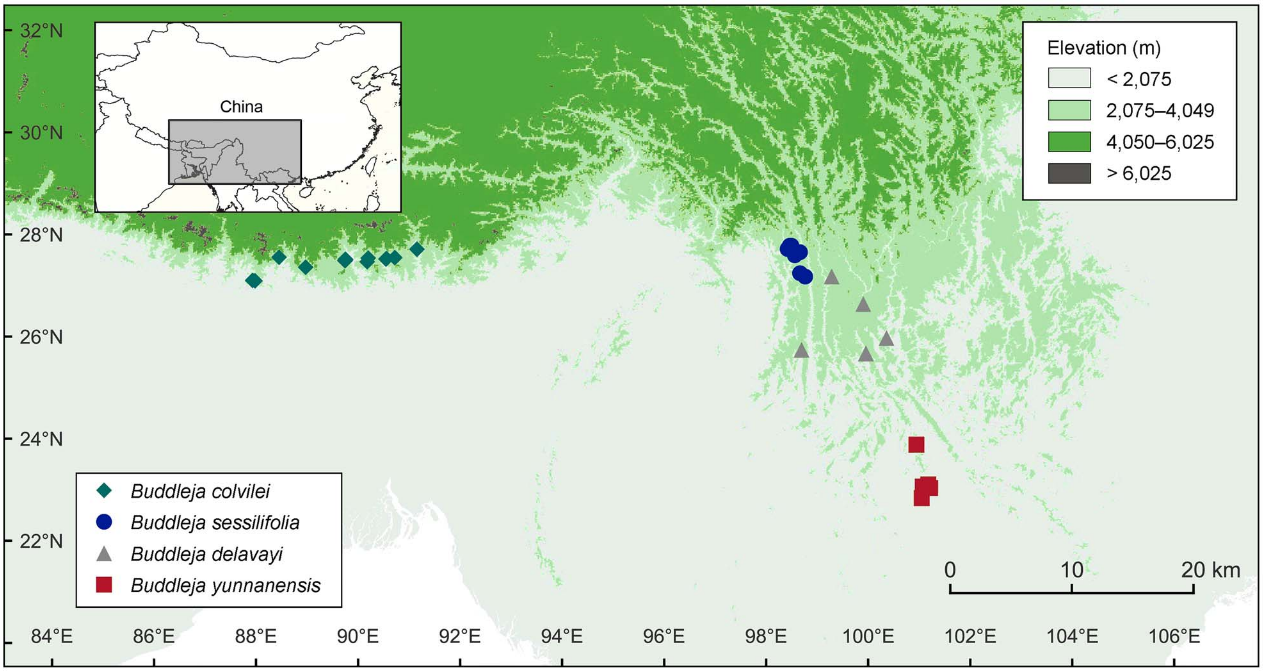

FIG. 1 Distribution of the four *Buddleja* species across the Himalayan region and south-western China.

Additionally, we excluded populations of *Buddleja heliophila* (considered a synonym for *B. delavayi*) because recent research by Ge et al. (unpubl. data, 2023) has revealed distinct molecular and morphological differences between them.

During our field surveys of the species and their habitats, we recorded habitat type, geographical coordinates (using a GPS), elevation, extent and impact of any human disturbance, and identified any other potential abiotic or biotic threats, using the IUCN Red List Threats Classification Scheme (IUCN, 2023b). We recorded the number of mature individuals in each location, and resurveyed each location 1–7 years after the first survey (Table 1). The assessment was conducted according to IUCN B and C criteria (IUCN, 2012, 2023b), considering area of occupancy, habitat status, number of mature individuals, and major threats.

From each population we collected healthy, mature seeds of 10 individuals with 1–3 infructescences, and recorded collection time and locality. We dried and cleaned the seeds, and deposited seeds of all four species in the National Wild Plant Germplasm Resource Centre at the Kunming Institute of Botany, China. We initiated ex situ conservation in Kunming Botanical Garden through tissue culture, cuttings and cultivation.

We implemented automated conservation assessment using the packages *red* and *ConR* in *R 4.2.2* (R Core Team, 2023) and *GeoCAT* (GeoCAT, 2023), which use only occurrence records. We retrieved data from GBIF (2023) using the *rgbif* package in *R* (Chamberlain & Boettiger, 2017; Chamberlain et al., 2024), and cross-checked these data with data from the Chinese Virtual Herbarium (2023). We filtered and cleaned data prior to automatic assessment. We excluded records with no location information or with a location outside of the species' native ranges according to Plants of the World Online (2023). We removed duplicates and records with misinformation based on knowledge from our field surveys. We cross-checked the remaining records with the Chinese Virtual Herbarium (2023) and Herbarium KUN, and added any missing data where required. We combined the resulting data with the occurrence records from our field surveys.

We estimated the extent of occurrence (the smallest polygon in which no internal angle exceeds 180° and that contains all occurrences) using the convex hull method, and we estimated the area of occupancy (the area within the extent of occurrence that is occupied by a taxon) using 2×2 km grid cells (IUCN, 2012). Using *ConR* we also estimated the number of locations and subpopulations using a sliding grid approach and a circular buffer method, respectively (Rivers et al., 2010). Using *red*, *ConR* and *GeoCAT* we determined the Red List category for each species based on validated IUCN B1 and/or B2 criteria (IUCN, 2012, 2023b).

Results

In our field surveys, we recorded 68 healthy, mature individuals of *B. colvilei* (2018), 29 of *B. delavayi* (2017), $>$ 532 of *B. sessilifolia* (2015, 2018, 2022) and 18 of *B. yunnanensis* (2022). After filtering and cleaning the data from a combination of field surveys and data from GBIF and the Chinese Virtual Herbarium, we had 14 unique occurrence records of *B.*

TABLE 1 Occurrence records of four *Buddleja* species endemic to the Himalayas, with latitude and longitude, collection years, location descriptors, data sources (Global Biodiversity Information Facility (GBIF), Chinese Virtual Herbarium (CVH) or observation from field surveys), and status (with the number of plants recorded in the respective collection years).

Latitude (N)	Longitude (E)	Collection years	Location	Source	Status (number of plants)[1]
Buddleja colvilei					
27°32′44″	90°43′16″	2022	Bumthang, Bhutan	GBIF	
27°5′32″	87°58′46″	1992, 2022	Chintapu, Ilam, Nepal	GBIF	
27°30′55″	89°45′12″	2021	Punakha, Thimpu, Bhutan	GBIF	
27°32′12″	90°11′57″	2020	Wangdue Phodrang, Bhutan	GBIF	
27°42′38″	91°9′20″	2019	Lhuentse, Bhutan	GBIF	
27°21′29″	88°58′19″	2015[2], 2018[3]	Yadong, Tibet, China	Observation	Decline (26/73)
27°5′57″	87°55′55″	2015[2], 2018[3]	Goruwale, Nepal	Observation	Decline (42/57)
27°31′8″	90°32′53″	2018	Trongsa, Bhutan	GBIF	
27°33′15″	88°27′6″	1884, 2023	Sikkim, India	GBIF	
Buddleja delavayi					
25°44′21″	98°41′46″	2006	Datang Cun, Yunnan, China	GBIF	
26°38′16″	99°54′23″	2012[2], 2017[3]	Jianchuang, Yunnan, China	Observation	Decline (29/40)
27°10′37″	99°17′13″	1940	Yunnan	GBIF[4]	
25°40′10″	99°56′28″	1929	Yunnan	GBIF[4]	
25°40′13″	99°57′29″	2018	Jianchuang, Yunnan, China	GBIF[4]	
25°58′18″	100°21′43″	2010[2]	Binchuang, Yunnan, China	Observation[4]	(4)
Buddleja sessilifolia					
27°42′55″	98°25′24″	2015[2], 2018[3]	Gongshan, Yunnan, China	Observation	Stable (> 300/> 300)
27°37′56″	98°35′51″	2015[2], 2018[3], 2022[3]	Gongshan, Yunnan, China	Observation	Decline (15/160)
27°35′31″	98°33′53″	2015[2], 2018[3]	Kachin Sate, Myanmar	Observation	Decline (110/133)
27°14′28″	98°39′59″	2015[2], 2018[3]	Kachin Sate, Myanmar	Observation	Decline (68/90)
27°46′48″	98°29′52″	2015[2], 2018[3], 2022[3]	Gongshan, Yunnan, China	Observation	Decline (2/20)
27°10′27″	98°46′2″	2010[2], 2015[3]	Fugong, Yunnan, China	Observation	Disappeared (0/28)
27°39′56″	98°31′10″	2021[2], 2022[3]	Gongshan, Yunnan, China	Observation	Stable (1/1)
27°46′47″	98°27′57″	2021[2], 2022[3]	Gongshan, Yunnan, China	Observation	Stable (36/36)
Buddleja yunnanensis					
23°3′45″	101°4′21″	2020[2], 2022[3]	Ninger, Yunnan, China	Observation	Decline (2/3)
23°1′56″	101°12′47″	2020[2], 2022[3]	Ninger, Yunnan, China	Observation	Decline (7/10)
23°2′3″	101°13′8″	2020[2], 2022[3]	Ninger, Yunnan, China	Observation	Stable (2/2)
23°6′14″	101°10′46″	2020[2], 2022[3]	Ninger, Yunnan, China	Observation[4]	Decline (5/6)
23°53′3″	100°57′1″	2020[2], 2022[3]	Zhenyuan, Yunnan, China	Observation[4]	Stable (1/1)
23°52′58″	100°56′55″	2020[2], 2022[3]	Zhenyuan, Yunnan, China	Observation[4]	Stable (1/1)
22°50′10″	101°3′4″	2012	Simao, Yunnan, China	CVH	

[1]Numbers indicate the number of mature plants recorded in the latest survey/first survey.
[2]Intial survey year.
[3]Year of resurvey.
[4]Recorded as *Buddleja heliophila*.

colvilei, eight of *B. sessilifolia*, six of *B. delavayi* (including *B. heliophila*) and seven of *B. yunnanensis* to use for automated assessment (Table 1). We found that all four *Buddleja* species had restricted distributions, with relatively small extents of occurrence and areas of occupancy, few occurrence locations and small populations (Table 2). All three automated assessments evaluated *B. delavayi* and *B. yunnanensis* as Endangered and *B. colvilei* and *B. sessilifolia* as Vulnerable, whereas our assessment based on our field studies is that both *B. delavayi* and *B. yunnanensis* should be categorized as Critically Endangered, *B. sessilifolia* as Endangered and *B. colvilei* as Vulnerable. The areas of occupancy calculated by the automated assessments were notably different from that of the field assessments, particularly for *B. sessilifolia* and *B. delavayi*.

Following the Red List criteria (IUCN, 2012), unique occurrences refer to cleaned and filtered records, subpopulations indicate distinct groups with limited genetic exchange, and locations are areas where a single threat can affect all individuals. The number of locations differs between the automated and traditional assessment methods (Table 2) because the former is based on unique occurrence records whereas the latter is based on direct field investigations.

Buddleja colvilei is widespread, but this species is at risk of extinction because of logging and harvesting of wood

Table 2 Conservation status of four *Buddleja* species, as assessed using *GeoCAT* (Bachman et al., 2011), *red* (Cardoso, 2017) and *ConR* (Dauby et al., 2017), on the Threatened Species List of China's Higher Plants (Qin et al., 2017), and based on our field assessment, with the calculated extent of occurrence (EOO) for each automated assessment and area of occupancy (AOO) for the automated and field assessments. Threat classification is based on IUCN (2023b).

	Automated assessment											Field assessment				
	GeoCAT		*red*		*ConR*											
Species	EOO (km^2)	AOO (km^2)	EOO (km^2)	AOO (km^2)	EOO (km^2)	AOO (km^2)	Number. of unique occurrences[1]	Number of subpopulations[1]	Number of locations[1]	Proposed IUCN category[2] (criteria)	Threatened Species List category (criteria)[2]	AOO (km^2)	Number of individuals	Number of locations	Threats	Proposed IUCN category (criteria)
B. colvilei	8,005	52	7,974	48	7,989	44	14	8	9	VU (B1a + B2a)	VU (A2c + 3c; D1)	14.78	81	2	Logging & wood harvesting (5.3.1), road construction (4.1)	VU (B2ab(iii)c(iv); C2a(i)b)
B. delavayi	15,758	20	15,694	20	15,694	20	6	4	5	EN (B2a)	VU (A2c)	0.14	29	1	Housing & urban areas (1.1), road construction (4.1)	CR (B2ab(iii)c(iv))
B. sessilifolia	897	32	894	32	894	32	8	5	6	VU (B1a + B2a)	NE	0.27	532	8	Road construction (4.1), debris flow (10.3)	EN (B2ab(ii)c(iv))
B. yunnanensis	1,125	20	1,120	20	1,120	20	7	4	5	EN (B1a + B2a)	VU (A2c; B1ab (i, iii, iv))	14.86	18	6	Housing & urban areas (1.1), shifting agriculture (2.1.1)	CR (B2ab(iii)c(iv))

[1]Results from *ConR* only.
[2]VU, Vulnerable; EN, Endangered; CR, Critically Endangered; NE, Not Evaluated.

(threat classification 5.3.1; IUCN, 2023b) and road construction (4.1). Of 57 *B. colvilei* plants originally recorded in Goruwale, Ilam, Nepal, we observed that 15 were cut and did not regenerate (Plate 1e). Only 26 were observed in Yadong, Tibet, China, with a 64% decline compared to the number of plants recorded in the original survey.

Although the combined records of *B. delavayi* demonstrate a large extent of occurrence, during our fieldwork in 2017 we found the species to be facing significant threats. It has a limited area of occupancy of 0.14 km^2, with only 29 individuals. Its habitat, which lies alongside a village roadside in Jianchuan County, Dali, appears to be at significant risk from housing and urban areas (threat 1.1) and road construction (4.1). The small number of mature individuals also poses a further severe risk of extinction. Our findings suggest that ex situ conservation is necessary to safeguard this species, and we have already implemented this: after 11 years of cultivation following their initial introduction in 2012, two individuals are thriving in Kunming Botanical Garden (Plate 1h).

The distribution of *B. sessilifolia* on Gaoligong Mountain reflects the fragmentation and isolated nature of its habitat. We recorded > 768 *B. sessilifolia* in total during our initial field surveys in 2010, 2015 and 2021. On returning to the sites in 2015, 2018 and 2022, respectively, although three populations remained stable, four had decreased, by 145 (91% decline), 23 (17%), 22 (24%) and 18 (90%) individuals. In addition, the population of 28 individuals in Fugong county had disappeared as a result of road construction (threat 4.1) and debris flow (10.3; Plate 1f). Despite our attempts, ex situ conservation of this species has so far failed because of the difficulty of establishing seedlings (Plate 1g).

Our field assessment of *B. yunnanensis* revealed that its distribution spans various habitats. However, these habitats are threatened by the development of housing and urban areas (threat 1.1) and shifting agriculture (2.1.1), posing a significant risk of extinction to this species from habitat loss and fragmentation. In Zhenyuan and Ninger counties, Yunnan, we found a small population of 18 individual plants with an area of occupancy of 14.86 km^2. This population lies outside any protected areas, in a region potentially prone to threats that would significantly impact survival. Despite our ex situ conservation efforts, the single individual that we had in cultivation died after 5 years.

Both the automated and field study assessments suggest *B. colvilei* should be categorized as Vulnerable. The automated assessments suggest classification under criteria B1a +B2a because of an extent of occurrence of $< 20{,}000$ km^2 (B1), area of occupancy of $< 2{,}000$ km^2 (B2) and documentation in < 10 localities (a). The field assessment further suggests classification under criteria B2ab(iii)c(iv); C2a(i)b, with observed declines (B2b) in area, extent and quality of habitat (iii), extreme fluctuations (c), the presence of $< 1{,}000$ mature individuals in locations (iv) and continuing decline (C2a) in the number of mature individuals within each subpopulation (i) along with extreme fluctuations in their numbers (b).

From our field studies, we propose that both *B. yunnanensis* and *B. delavayi* are categorized as Critically Endangered based on criteria B2ab(iii)c(iv) because their area of occupancy is < 10 km^2 (B2), with a severely fragmented habitat (a), continuous decline observed (b) in area, extent and quality of habitat (iii), and significant fluctuations (c) in the number of locations (iv), with only 29 mature individuals of *B. delavayi* and 18 of *B. yunnanensis* recorded.

Also from our field studies, we propose that *B. sessilifolia* is categorized as Endangered based on criteria B2ab(ii)c(iv) because of its area of occupancy < 500 km^2 (B2), fragmented distribution occurring at no more than five locations (Gongshan, Yunnan and Kachin, Myanmar) (a), continuous decline (b) in its area of occupancy (ii), and significant fluctuations (c) in the number of mature individuals (iv) due to multiple threats (4.1 and 10.3).

Discussion

Of the 36 globally significant biodiversity hotspots, three (Eastern Himalayas, Indo-Burma, and the Mountains of Southwest China) are in the Himalayan region (CEPF, 2023) and have a high conservation priority. Circa 45.1% of the world's angiosperm species are potentially under threat (Bachman et al., 2024). Therefore, conservation assessments are critical for the identification of threatened species and for the development of conservation plans, but different assessment methods can provide varying degrees of accuracy and reliability. Automated assessments are based solely on georeferenced data, whereas field studies incorporate additional parameters such as habitat status, number of mature individuals and threats. However, both methods highlighted the precarious status of these four species of Himalayan *Buddleja*.

The Threatened Species List of China's Higher Plants (Qin et al., 2017) is an expert-driven assessment that covers a large number of species. Although it can be informative, the categorizations may not consider all nuances of the ecology and behaviour of a species and can also be subject to bias. Three of the four *Buddleja* species we assessed have been categorized on the Threatened Species List, but two of these categorizations, for *B. delavayi* and *B. yunnanensis*, are markedly different from our field assessment (Vulnerable as opposed to Critically Endangered). This could be attributed to the limited availability of long-term investigations and the reliance on checklist data from various databases.

Conversely, automated assessment tools are fast, efficient and cost-effective, can provide preliminary conservation assessments for large numbers of species, and can minimize bias and incorporate a wide range of data. The utilization of three tools (*GeoCAT*, *red* and *ConR*), each with unique features, can help to support field investigations, and in our study the estimated extents of occurrence and areas of occupancy (Table 2) were consistent across all tools.

ConR seems to be the most useful of the three tools because it computes the number of geographical locations in which a species is present. This could be a key determinant of the conservation status of a species because it may indicate the level of habitat fragmentation, which may in turn highlight threats facing a particular species. For example, the latest data on *B. colvilei* revealed a high abundance in Bhutan (Table 1) that we could not ascertain through our field studies, highlighting the importance of field surveys in this region. At the same time, it is important to exercise caution when using open-source databases for conservation assessments as intensified anthropogenic stresses and climate change may cause a decline in species occurrences, affecting the results of assessments. In cross-checking records with herbarium specimens, we found instances of mislabelled specimens. Making automated assessments with mislabelled records could lead to incorrect conclusions, as evidenced by the evaluation of *B. delavayi* as Endangered rather than Critically Endangered.

Automated assessments may not be as reliable as other methods, however, as they do not consider the number of individuals in a population or specific threats. Field surveys are generally considered the most accurate method for assessing extinction risk (Nic Lughadha et al., 2018) as they provide detailed information on species' distribution, population sizes and threats. Anthropogenic activities such as road construction related to the national or local prioritization of development works and population growth must be considered when prioritizing conservation intervention. Our field surveys of *B. sessilifolia* revealed it is facing a significant risk because its habitat is being fragmented by roads and damaged by mudslides. Similarly, our surveys indicated concern regarding the status of *B. yunnanensis*, with its limited distribution and a decline in the quality of its habitat resulting in it being catalogued as a Plant Species with an Extremely Small Population. Our field surveys revealed significant threats to these species, highlighting the conservation challenges they face, including habitat degradation, fragmentation and loss, and the negative impacts of anthropogenic activities. However, field surveys can be costly in terms of time and resources, making it difficult to survey large numbers of species.

Although automated assessments are recommended for a preliminary evaluation of conservation status (Zizka et al., 2021), our comparison of methods revealed their limited effectiveness for our focal species. Automated assessments are particularly suitable for species with a wide range of distribution records (Palacio et al., 2021) and for which there are constraints on field surveys, as in the case of *B. colvilei* in Bhutan and India. We acknowledge, however, that the paucity of accurate distribution data and taxonomic ambiguity could limit the effectiveness of automated assessment (Mackay-Smith & Roberts, 2019).

Our findings revealed significant issues with digitized information, including identification of errors (e.g. the treatment of *B. delavayi* and *B. heliophila* as the same species) and lack of up to date information (e.g. the Fugong population of *B. sessilifolia* recorded in 2010 that had disappeared by 2015), which may have adversely affected the outcomes of our automated assessments (AuBuchon-Elder et al., 2023). We recommend increasing the digitalization of information for occurrence records, implementing cleaning and filtering processes and establishing user-friendly platforms for data feedback and integration into data repositories such as the Global Biodiversity Information Facility. Only with field exploration and the collection of first-hand data can we fill gaps in the knowledge of species distributions (Nic Lughadha et al., 2018).

In our case study, field surveys provided the most accurate information for evaluating conservation status, particularly for range-restricted species, because they provided direct and informative data, which is essential when other data are limited or unavailable. Our study therefore highlights the importance of making assessments using data from field surveys when information on a species is limited or unavailable.

Because the Himalayan region is home to many endemic species, a multifaceted approach combining multiple sources of accurate information can contribute to a more comprehensive and reliable species conservation plan than any one approach alone. We recommend first conducting a preliminary assessment using automated assessment methods and then carrying out field surveys for validation and detailed analysis.

Our study also highlights the need for further research on the ecology and conservation biology of threatened species. This could include studies of conservation genetics, responses to different environmental stressors, and interactions with other species, such as pollination biology. (Chen et al., 2012; Ollerton, 2017; Coates et al., 2018; Nonić & Šijačić-Nikolić, 2019). In addition, scientifically sound conservation efforts are needed to protect such species and their habitats, including the identification of threats, habitat restoration, in situ or ex situ conservation (or both) and public education and outreach (Ma et al., 2013; Volis, 2016; Chen & Sun, 2018). Many plant species face serious threats in the Himalayan region, and targeted and comprehensive conservation measures are required. Overall, our study emphasizes the need for a more integrated conservation approach to address the constraints currently hampering species conservation in this region.

Author contributions Study design: JG, GC; fieldwork: all authors; data analysis: BG, JG; writing: BG, JG.

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Conflicts of interest None.

Ethical standards Investigation and collection of plant materials were with the permission and under the supervision of the relevant local authorities. This research abided by the *Oryx* guidelines on ethical standards.

Data availability The authors confirm that the data supporting the findings of this study are openly available via the Global Biodiversity Information Facility at doi.org/10.15468/dl.nkxucp.

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