The value of flagship and umbrella species for restoration and sustainable development: Bale monkeys and bamboo forest in Ethiopia

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Abstract

Forest loss and degradation are the most significant threats to terrestrial biodiversity in the tropics. Promoting flagship or umbrella species is a strategy that can be used to conserve intact forests and restore degraded ecosystems, conserve biodiversity, and achieve sustainable development goals. The Bale monkey (*Chlorocebus djamdjamensis*) is an arboreal, forest-dwelling, threatened primate restricted to a small range in the southern Ethiopian Highlands, which relies mostly on a single species of bamboo (*Arundinaria alpina*) and prefers bamboo forest habitat. Most of the Bale monkey's range lies outside protected areas and most of its historical bamboo forest habitat is degraded or destroyed. The conservation of Bale monkeys and bamboo is highly inter-dependent; however, the value of using the Bale monkey as a flagship or umbrella species for forest restoration has not been evaluated. Here we use geographic range overlap and geospatial modeling to evaluate Bale monkeys as a flagship and/or umbrella species. We also assess if conservation intervention on behalf of Bale monkeys can help restore bamboo forest, while simultaneously providing a wide range of socioeconomic and environmental benefits. We found that Bale monkeys share their range with 52 endemic and/or threatened vertebrate species and at least 9 endemic and/or threatened plant species. Our results show that Bale monkeys meet both the flagship and umbrella species criteria to restore bamboo forest and conserve threatened co-occurring species. Since bamboo is fast-growing and can be harvested every year, we suggest that a science-based sustainable harvest and management regime for bamboo would help to improve the livelihood of both the local community and Ethiopians in general without significantly affecting the long-term survival of Bale monkeys and regional biodiversity. Further, a conservation management strategy protecting and restoring bamboo forest has the potential to achieve at least six of the 17 United Nations Sustainable Development Goals.

Keywords: Bamboo restoration, *Chlorocebus djamdjamensis*, Deforestation, Ecosystem restoration, Sustainable Development Goals

Introduction

One of the most important challenges humanity faces is how to prevent species extinctions (Ceballos et al., 2017), and in terrestrial systems the leading threat is forest degradation and loss (Gibson et al., 2011; Haddad et al., 2015; Newbold et al., 2015). Globally, ~60 million ha of tropical primary forest were lost from 2002 to 2019, with most forest loss occurring in Brazil (24.5 Mha), Indonesia (9.5 Mha), and the Democratic Republic of the Congo (4.8 Mha) (Weisse and Goldman, 2020). To put this in perspective, an area of old-growth tropical forest larger than Madagascar was lost in just 18 years. As a result, integrating forest restoration and landscape connectivity in land-use planning is a critically important strategy for achieving biodiversity conservation, climate change corrections, and other sustainable development goals (Chazdon and Brancalion, 2019; Heller and Zavaleta, 2009; Lewis et al., 2019).

Funding limitations lead conservationists to prioritize some species over others, focusing especially on those with the greatest potential conservation impacts (Caro, 2010; Rodrigues and Brooks, 2007). As a result, the use of flagship and umbrella species has become an extremely valuable strategy for restoration and biodiversity conservation (Caro, 2010; Rodrigues and Brooks, 2007; Shen et al., 2020; Thornton et al., 2016). Flagship species are taxonomically distinctive, threatened, and charismatic species that can serve as icons for conservation efforts (Bowen-Jones and Entwistle, 2002; Chapman et al., 2020; Macdonald et al., 2017). Flagship species are usually selected based on socio-cultural factors, which influence their ability to generate funding and to promote public awareness (Bowen-Jones and Entwistle, 2002; Caro, 2010; Simberloff, 1998). Well-known examples of flagship species include giant pandas (*Ailuropoda melanoleuca*) for the restoration and conservation of bamboo forest ecosystems in western China (Li and Pimm, 2016; Shen et al., 2020), snow leopards (*Panthera uncia*) for the conservation of alpine ecosystems in Central Asia (Shen et al., 2020), and Ethiopian wolves

(*Canis simensis*) for the conservation of Afroalpine ecosystems in the Ethiopian Highlands (Tefera and Sillero-Zubiri, 2007).

On the contrary, umbrella species are species with specific habitat requirements for which restoration and protection of their habitat benefits many other co-occurring species (Caro, 2010; Roberge and Angelstam, 2004; Thornton et al., 2016; Ward et al., 2020). The effectiveness of umbrella species depends on their spatial range overlap with other species of conservation concern and the ability to protect the habitat quality and viability of other co-occurring species of interest (Branton and Richardson, 2014; Breckheimer et al., 2014). For example, restoring and connecting habitat for jaguars (*Panthera onca*) provides a substantial amount of high-quality habitats for other co-occurring terrestrial mammals in Latin America (Thornton et al., 2016). Similarly, forest restoration and conservation for giant pandas has major benefits for several co-occurring endemic mammals and birds in China (Li and Pimm, 2016). Smaller-bodied and small range species with specialized habitat requirements can serve as umbrella species if their conservation simultaneously benefits many other species that share their habitat. For example, any conservation intervention for koalas (*Phascolarctos cinereus*) in woodland habitats in Australia not only benefits the koalas but also benefits at least 10 other threatened co-occurring species (Ward et al., 2020). Similarly, management actions for regent honeyeaters (*Anthochaera phrygia*) in temperate forests and red goshawks (*Erythrotriorchis radiates*) in tropical forests benefit seven and five additional threatened co-occurring species, respectively (Ward et al., 2020).

A species can serve as both a flagship and umbrella species (Caro, 2010; Li and Pimm, 2016; Shen et al., 2020). The best-known example of a flagship-umbrella is the panda because their conservation generates enormous public interest and benefits many species inhabiting bamboo forests (Li and Pimm, 2016; Shen et al., 2020). Bale monkeys (*Chlorocebus djamdjamensis*), which, like pandas, depend exclusively on bamboo (Schaller, 1985), are

medium-sized (adult weight: 4.9 - 6.4 kg) Old-World primates endemic to southern Ethiopia. Bale monkeys depend primarily on a single species of bamboo (*Yushania alpina*; synonym: *Arundinaria alpina* hereafter bamboo) as a food source and prefer bamboo forest habitat (Mekonnen et al., 2010a; Mekonnen et al., 2010b; Mekonnen et al., 2017; Mekonnen et al., 2018a).

Here we use geographic range overlap and geospatial modeling to evaluate Bale monkeys as a flagship and/or umbrella species for the restoration of bamboo forest ecosystems and conservation of sympatric fauna and flora in the southern Ethiopian Highlands. Specifically, we (1) evaluate the conservation threats Bale monkeys face; (2) identify the other threatened and/or endemic species that are sympatric with Bale monkeys; and finally (3) discuss the potential benefits of Bale monkey conservation interventions (e.g., restoration and protection of bamboo forest) to achieving United Nations Sustainable Development Goals (SDGs).

Methods

Study species and habitats

Ethiopia has only two indigenous bamboo species, highland (*A. alpina*) and lowland bamboo (*Oxytenanthera abyssinica*) (Embaye, 2000; Embaye et al., 2005). Highland bamboo covers ~330,000 ha and is found scattered in pockets across parts of southern and western Ethiopia (Embaye, 2000; Zhao et al., 2018). The range of Bale monkeys in southern Ethiopia harbors substantial areas of highland bamboo as these montane forests are protected in part by their remoteness and the mountainous terrain of the Bale Mountains (Fig. 1) (Embaye, 2000; Mekonnen et al., 2010b; Zhao et al., 2018). However, most of the bamboo forest remaining in the Sidamo Highlands is degraded or nearly eradicated due to agricultural expansion, human settlement, logging, and grazing land expansion (Gippoliti et al., 2019; Mekonnen et al., 2012). Even these degraded areas have significant conservation potential as bamboo is the fastest-

growing non-timber plant and matures much earlier than co-occurring timber plants (Liese and Köhl, 2015). Bamboo can be harvested within 4 years after planting and subsequently provides consistent yields every year (Ben-Zhi et al., 2005).

Although the Bale monkey was first described as a species in 1902, it was generally neglected until it was rediscovered in 1990 (Carpaneto and Gippoliti, 1994) and revalidated as a species a decade later (Groves, 2005). Over the past decade, however, intensive studies have been conducted on the ecology, behavior, genetics, gut microbiota, and conservation biology of Bale monkeys in southern Ethiopia (Mekonnen et al., 2017; Mekonnen et al., 2018c; Trosvik et al., 2018). The Bale monkey is an arboreal bamboo-specialist restricted to a narrow geographic range in the southern Ethiopian Highlands (Gippoliti et al., 2019; Mekonnen et al., 2018b). The Bale monkey is classified as Vulnerable with populations declining due to habitat loss, degradation, and fragmentation, hunting, and possible hybridization with vervets and grivets (Gippoliti et al., 2019). It is restricted to an estimated 12,500 km^2 in the bamboo forest habitats in the Bale Mountains and isolated forest fragments in the Sidamo Highlands (Gippoliti et al., 2019; Mekonnen et al., 2012; Mekonnen et al., 2010b) (Fig. 1). Bale monkeys prefer high elevation (2,355 to 3,300 m asl) bamboo forests over the other available habitat types, including tree-dominated forest, bushland, and grassland habitats (Mekonnen et al., 2012; Mekonnen et al., 2010b). Most populations do not occur in protected areas except those in Bale Mountains National Park (BMNP) (Gippoliti et al., 2019; Mekonnen et al., 2012; Mekonnen et al., 2010b).

In continuous forest, Bale monkeys are dietary specialists, devoting 77-81% of their feeding time to highland bamboo, focusing mostly on its young leaves and shoots (Mekonnen et al., 2010a; Mekonnen et al., 2018a). In a forest fragment where bamboo stands are still present but degraded, bamboo accounts for 30% of Bale monkey feeding time, while in another fragment where bamboo has been largely eradicated, bamboo only constitutes 2% of their feeding time (Mekonnen et al., 2018a). In these fragments, they also consume fruits, forbs, and

graminoids, including cultivated food species (Mekonnen et al., 2018a), which account for 0.2-10.3% of their feeding time depending on the degree of fragment degradation (Mekonnen et al., 2020b).

Assessment of flagship and umbrella species characteristics

To assess whether the Bale monkey can serve as a *flagship species* for the conservation of highland bamboo, we considered if Bale monkey was taxonomically distinctive, threatened, and if it is considered a charismatic species by an international audience and by local people in the highlands of Ethiopia.

To assess whether Bale monkeys serve as an *umbrella species*, as preliminarily suggested by Gippoliti (2020), we performed a comprehensive analysis to identify species that share geographic range and habitat with Bale monkeys. We compiled a list of all the endemic and/or threatened mammal, bird, reptile, and amphibian species in Ethiopia from the IUCN Red List and BirdLife International (Birdlife International, 2020; IUCN, 2020) (Appendix A). Because we lack data on the invertebrates that share the range of Bale monkeys, we are unable to assess the importance of Bale monkeys as an umbrella species for invertebrate conservation. However, we also compiled a list of the endemic and/or threatened vascular plant species in Ethiopia (cf., Asefa et al., 2020; IUCN, 2020). We consider a species endemic if its range falls entirely within Ethiopia's boundaries. We consider a species threatened if it is classified as Vulnerable, Endangered, or Critically Endangered in the most recent IUCN Red List (IUCN, 2020). We identified 128 endemic and/or threatened terrestrial animal species for Ethiopia, including 66 mammal species, 46 bird species, 11 amphibian species, and 5 reptile species (Appendix A). Among these species, 80 are endemic (45 mammal, 20 bird, 11 amphibian, and 4 reptile species) to Ethiopia and 84 (38 mammal, 36 bird, 9 amphibian, and 1 reptile species) are classified as threatened (Appendix A). We also compiled a total of 518 endemic and/or

threatened plant species for Ethiopia. Of these, 489 species are endemic (19 tree, 133 shrub, 278 herb, 35 grass, 10 epiphyte, 12 climber and 2 geophyte species) to Ethiopia and 60 (22 tree, 31 shrub, 6 herb and 1 climber species) are classified as threatened (Appendix B). In addition, the IUCN (2020) classifies 9 endemic mammal and 8 endemic plant species as Data Deficient; based on our experience we consider these species as threatened though we did not include them in our analyses.

We extracted the geographic range map (extent of occurrence) of each endemic and/or threatened species from the IUCN Red List. Although the IUCN range polygons provide useful information regarding the species' geographic boundaries, they incorporate some areas that are not suitable for a particular species (Li and Pimm, 2016). Thus, we collected elevational range and primary habitat data for each animal species from BirdLife International, the IUCN Red List, and supplemental missing elevational data from the literature.

We produced species richness maps across Ethiopia using Spatial Analysis in Macroecology (SAM) version 4.0 (Rangel et al., 2010) and ArcGIS 10.8.1 to identify the concentration of threatened species and centers of endemism by summing the range map for each threatened, endemic, and threatened and/or endemic animal species as well as for all terrestrial animal species. We estimated species richness by the total count of species recorded in each grid cell ($0.1^{o} \times 0.1^{o}$ latitude–longitude resolution, i.e., 11 × 11 km) built in SAM software. We did not produce richness maps for endemic and threatened plants of Ethiopia due to a lack of IUCN range polygon data for most species.

Results

Conservation threats of Bale monkeys

The primary threat facing Bale monkeys is deforestation and the unsustainable harvesting of bamboo (Mekonnen et al., 2012; Mekonnen et al., 2017; Mekonnen unpublished data). They

are still locally abundant in the remaining continuous bamboo forests of the Bale Mountains, but in the Sidamo Highlands there are <800 individuals occurring in more than two dozen forest fragments (Gippoliti et al., 2019; Mekonnen et al., 2012; Mekonnen et al., 2010b). Bale monkeys are threatened in these forest fragments by hunting that occurs in response to their crop raiding on barley, maize, vegetables, fruits, bamboo, and enset (*Ensete ventricosum*) (Mekonnen et al., 2012; Mekonnen et al., 2018a; Mekonnen et al., 2020b). Local people reported intense conflict with Bale monkeys in all 26 known localities in the Sidamo Highlands and people have extirpated populations at other sites (Mekonnen et al., 2012).

Bale monkeys are also threatened by climate change. As these animals only occur at high-altitude, their ability to respond by moving is limited (Mekonnen et al., 2012). Genetic and morphological studies (Mekonnen et al., 2012; Mekonnen et al., 2018c) indicate that Bale monkeys are also threatened by hybridization with the more widespread and adaptable grivet (*C. aethiops*) and vervet monkeys (*C. pygerythrus*) in the zones of contact that are found in degraded and fragmented sections of the range of Bale monkeys (Gippoliti et al., 2019; Mekonnen et al., 2012; Mekonnen et al., 2018c). Further degradation of their montane forest habitat would surely lead to more hybridization of Bale monkeys with these other *Chlorocebus* species (Mekonnen et al., 2012; Mekonnen et al., 2018c).

Bale monkey as a flagship and umbrella species

The Bale monkey is a visually striking animal (Fig. 2) that inhabits an unusual bamboo forest ecological niche that people in high-income nations know little about but are intrigued by (Bourton, 2010). These traits, combined with the fact that primates often receive special attention in fund raising efforts (Chapman et al., 2020), means that Bale monkeys can serve as a flagship species, bringing international attention to the need to conserve them and their bamboo habitat (Table 1).

The range of Bale monkeys overlaps with the ranges of 52 other endemic and/or threatened vertebrates. Of these vertebrates, 31 are endemic to Ethiopia, 36 are classified as threatened in the IUCN Red List, and 15 are both threatened and endemic species (Table 2, Table 3, Fig. 3). Of the 15 threatened endemic species that overlap with Bale monkeys, 8 are mammals, 1 is a bird and 6 are amphibians (Table 2, Table 3). Further, the Bale monkey shares its forest habitat with 30 other endemic and/or threatened species that inhabit forest habitats, of which 19 are endemic to Ethiopia, 22 are threatened and 11 are both threatened and endemic. The range of Bale monkeys also overlaps with the ranges of 9 endemic and/or threatened plant species, of which, 7 are endemic to Ethiopia, 3 are threatened and 1 species is both threatened and endemic to Ethiopia (Table 4).

Discussion

We have demonstrated that the Bale monkey can act as an umbrella species and that taking action to protect them will advance conservation efforts for many other animals and plants. We also provide evidence that Bale monkeys can act as a flagship species to attract international funding. Here, we consider what actions will be useful to undertake to protect Bale monkeys and their bamboo forest habitat in Ethiopia. However, it must be recognized that Bale monkeys destroy people's crops. As a result, conservation and restoration plans must be intentionally designed to reduce crop feeding by the monkeys and to provide benefits to the local people. This approach would ensure that the crop losses that local people do experience are offset by other economic gains resulting from bamboo restoration and ecotourism projects and by a sincere appreciation that conservation and restoration actions in Bale monkey habitats are helping Ethiopia's wildlife and international status (i.e., they have pride in helping conservation).

Bale monkey as a flagship and umbrella species

Our study highlights a link between the Bale monkey's charismatic nature and its ability to serve as a flagship species for the conservation of bamboo forest habitat and many co-occurring species in the region. Flagship species that occur in high conservation priority areas can enhance their value in terms of their potential for conservation marketing (e.g., to create awareness about the importance of biodiversity conservation in the region and to raise funding) (Caro, 2010; Macdonald et al., 2017). Because the Bale monkey inhabits Ethiopia's important bamboo forest ecosystem characterized by high biodiversity, endemism, and vulnerability to habitat alteration and climate change, the species is marketable to the international and national community. Given that Bale monkeys in the most degraded fragments in their human-dominated landscape damage cultivated foods, thereby competing with nearby people who want to harvest crops, local people are unlikely to consider them flagship species in the areas where there is intense conflict between people and monkeys. However, restoration of degraded and marginal forest fragments with bamboo and indigenous food and sleeping tree species can reduce or stop entirely such conflict, thereby helping to facilitate more sustainable coexistence between local people and the monkeys (Mekonnen et al., 2020b; Mekonnen et al., 2021). In areas with little or no human-Bale monkey conflict, local people might over time come to view Bale monkeys more favorably and ultimately as a flagship species. Furthermore, as they continue to attract international attention through research and conservation activities (Bourton, 2010) and potentially draw in tourists, Bale monkeys will come to be viewed as a flagship species by Ethiopian governmental agencies and businesses. Overall, this suggests that the Bale monkey can serve as a flagship species nationally and internationally to raise funds for conservation and restore and protect the bamboo forest ecosystem in the Ethiopian Highlands internationally and nationally (Table 1). Thus, we recommend establishing and expanding pilot bamboo restoration and reforestation projects in the Sidamo Highlands. Non-governmental organizations, funding

bodies, private companies, and research institutions could help lead the way in supporting bamboo restoration and reforestation projects because local people cannot be expected to pay for conservation in low income countries such as Ethiopia (Garnett and Thomson, 2020).

We suggest that 52 endemic and/or threatened vertebrate and at least 9 endemic and/or threatened plant species in southern Ethiopia have ranges that overlap with that of Bale monkeys (Table 2). This range and habitat overlap means that any conservation intervention for Bale monkeys, such as restoration and protection of bamboo habitats, would also benefit many co-occurring threatened and/or endemic mammals, birds, amphibians, reptiles and plants in the southern Ethiopian Highlands (Table 2, 3 and 4). Thus, like the giant panda in bamboo forest habitat in China (Li and Pimm, 2016), the Bale monkey is promising as both a flagship species and an umbrella species for the restoration and protection of bamboo forest at the landscape level in southern Ethiopia.

Of the 489 endemic plant species recorded in Ethiopia, 425 are Not Evaluated, and 8 are recorded as Data Deficient by IUCN (IUCN, 2020). Therefore, we suggest urgent IUCN Red List assessment for these endemic species because they generally have more significant global conservation concerns, smaller geographic ranges, smaller population sizes, fewer potential sites for conservation intervention, and overall greater vulnerability to extirpation and extinction than non-endemic species (Brooks et al., 2006; Mekonnen et al., 2020a). Bale monkey habitat protection will likely benefit many of the species/subspecies that are not evaluated. A comprehensive biodiversity assessment in the region occupied by the Bale monkey that includes plants, insects, and other invertebrates (Green et al., 2015; Kalinkat et al., 2017) is needed.

Bamboo forest restoration and conservation strategies in the range of Bale monkeys

A conservation strategy protecting and restoring bamboo forest has the great potential to achieve a wide range of socioeconomic and environmental benefits associated with the United Nations Sustainable Development Goals (SDGs). The SDGs were adopted by the UN General Assembly in 2015 and consist of 17 goals (UN General Assembly, 2015). Here we summarize the potential contributions of bamboo forest restoration and sustainable use to achieving 6 of the 17 SDGs (Fig. 4).

Contribution to poverty reduction (SDG1): Restoration of bamboo will provide several socioeconomic benefits for local people as bamboo is used for making crafts, household goods, fences, charcoal, and serves as a raw material for building construction, paper, textile, and timber production (Akwada and Akinlabi, 2020; Embaye, 2000; Partey et al., 2017; Sawarkar et al., 2020). Presently, bamboo culms are one of the major sources of income next to agriculture in southern Ethiopia (Embaye, 2000; Teshale et al., 2017). Bamboo shoots are also consumed by local people (Embaye, 2000; Satya et al., 2012) and their leaves are used as livestock feed when there are dry season feed shortages (Mekuriaw et al., 2011).

Contribution to clean and affordable energy (SDG 7): Bamboo forest restoration and sustainable cultivation can generate affordable and clean energy. Fuelwood consumption and charcoal production is the second biggest anthropogenic cause of forest loss and fragmentation in tropical Africa after agricultural expansion (FAO, 2010; MacDicken, 2015). Urbanization and limited access to electricity and its high cost are expected to increase the demand for fuelwood and charcoal consumption (Adkins et al., 2012). Bamboo charcoal is relatively cheap, renewable, and less toxic than wood charcoal (Lobovikov et al., 2007). Thus, bamboo could be used as an alternative and sustainable energy resource, thereby reducing deforestation (Nitayaphat et al., 2009; Van Khuc et al., 2018)

Contribution to sustainable cities and communities (SDG 11): Restoration and protection of bamboo can contribute to the achievement of sustainable cities and communities

because it can be used as a raw material for constructing furniture and bamboo-based sustainable houses (Ling et al., 2016; Salzer et al., 2016). Bamboo is already widely used for building traditional homes by the Sidama and Oromo people in the countryside (Fig. 5). It is also flexible, durable, relatively cheap, abundant, renewable, and much stronger than wood and brick (Puri et al., 2017; Scurlock et al., 2000). Thus, bamboo is an environmentally friendly alternative resource for building low-cost houses in towns and cities (Manandhar et al., 2019; Puri et al., 2017).

Contribution to responsible production and consumption (SDG 12): Due to its fast growth, bamboo can be a source of sustainable bioenergy and green building materials as well as a sustainable substitute for tropical forest wood or cotton in the bioenergy, construction, and manufacturing industries (Manandhar et al., 2019; Nayak and Mishra, 2016). Generally, bamboo has a low negative environmental impact throughout its life cycle, uses less energy than conventional materials, and generates little waste during its processing and production stages and what it does produce is bio-degradable. Thus, industrial products made from bamboo are often considered eco-friendly (Hardin et al., 2009; Manandhar et al., 2019).

Contribution to climate action (SDG 13): Bamboo forest restoration and protection can combat climate change through the sequestration of CO_2 from the atmosphere, which will create carbon trade opportunities (Lobovikov et al., 2012; Nath et al., 2015) and generate additional income for the local community (Dwivedi et al., 2019; Nath et al., 2018).

Contribution to life on land (SDG 15): Bamboo forest restoration and conservation can promote biodiversity conservation (e.g., as a food source and wildlife habitat) by rehabilitating degraded mountainous lands (Bystriakova et al., 2004; Embaye, 2000; Kaushal et al., 2020). Adequately managed afforestation of bamboo has enormous restoration potential for biodiversity conservation because bamboo is fast-growing and adapted to grow on degraded, marginal, and mountainous lands unsuitable for traditional agriculture (Ben-Zhi et al., 2005;

Yen and Lee, 2011). Restoration of bamboo improves soil quality, prevents soil erosion, sequesters carbon in the soil, and enhances water retention (Kaushal et al., 2020; Lu et al., 2018). The Bale Mountains and Sidamo Highlands are generally not suitable for traditional agriculture and are highly vulnerable to soil erosion, thus bamboo restoration and protection here has tremendous potential to conserve biodiversity and achieve SDG 15.

Conclusions

Bale monkeys are bamboo specialist species adapted to narrow geographic ranges, habitats, and dietary niches, which make them highly vulnerable to habitat fragmentation and degradation. Ethiopian bamboo is regarded as the "new green gold of Africa" (McKenna, 2013; Nurse, 2016) because of its potential for generating income and reducing poverty. This offers many potential opportunities for conservation. However, large-scale use of bamboo for local consumption and commercial purpose requires a science-based management plan to improve the local community's livelihood and ensure sustainable use without significantly affecting the long-term survival of Bale monkeys and regional biodiversity.

We suggest that Bale monkeys could serve as a flagship and umbrella species for restoration and conservation efforts in southern Ethiopia. Bamboo forest restoration and protection will provide important habitat, increase fragment connectivity, and reduce the use of cultivated foods and the resulting human-wildlife conflict. Furthermore, appropriate bamboo restoration and management strategies will also help to achieve at least six SDGs (SDG 1, SDG 7, SDG 11, SDG 12, SDG 13, and SDG 15) and conserve sympatric biodiversity in the tropics.

Author Contributions: AM, PJF, CAC, VVV, and NCS conceived and designed the study. AM collected and analyzed the data. AM, PJF, CAC, VVV, and NCS wrote the manuscript.

Declaration of Competing Interest

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

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References

Adkins, E., Oppelstrup, K., Modi, V., 2012. Rural household energy consumption in the millennium villages in Sub-Saharan Africa. Energy Sustain. Dev. 16, 249-259.

Akwada, D.R., Akinlabi, E.T. (2020). Industrial Applications of Bamboo in Ghana, Singapore.

Asefa, M., Cao, M., He, Y., Mekonnen, E., Song, X., Yang, J., 2020. Ethiopian vegetation types, climate and topography. Plant Divers. 42, 302-311.

Ben-Zhi, Z., Mao-Yi, F., Jin-Zhong, X., Xiao-Sheng, Y., Zheng-Cai, L., 2005. Ecological functions of bamboo forest: research and application. J. For. Res. 16, 143-147.

Birdlife International, 2020. IUCN Red List for birds. http://www.birdlife.org. Accessed 20 December 2020.

Bourton, J. (2010). Mysterious Bale monkey of Africa loves to eat bamboo. *BBC Earth News*. Retrieved from http://news.bbc.co.uk/earth/hi/earth_news/newsid_8587000/8587712.stm

Bowen-Jones, E., Entwistle, A., 2002. Identifying appropriate flagship species: the importance of culture and local contexts. Oryx 36, 189-195.

Branton, M.A., Richardson, J.S., 2014. A test of the umbrella species approach in restored floodplain ponds. J. Appl. Ecol. 51, 776-785.

Breckheimer, I., Haddad, N.M., Morris, W.F., Trainor, A.M., Fields, W.R., Jobe, R.T., et al., 2014. Defining and evaluating the umbrella species concept for conserving and restoring landscape connectivity. Conserv. Biol. 28, 1584-1593.

Brooks, T.M., Mittermeier, R.A., da Fonseca, G.A., Gerlach, J., Hoffmann, M., Lamoreux, J.F., et al., 2006. Global biodiversity conservation priorities. Science 313, 58-61.

Bystriakova, N., Kapos, V., Lysenko, I., 2004. Bamboo biodiversity: Africa, Madagascar and the Americas, edn. UNEP/Earthprint.

Caro, T., 2010. Conservation by proxy: indicator, umbrella, keystone, flagship, and other surrogate species, edn. Island Press.

Carpaneto, G.M., Gippoliti, S., 1994. Primates of the Harenna Forest, Ethiopia. Primate Conserv. 11, 12-15.

Ceballos, G., Ehrlich, P.R., Dirzo, R., 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. Proc. Natl. Acad. Sci. 114, E6089-E6096.

Chapman, C.A., Bicca-Marques, J.C., Dunham, A.E., Fan, P., Fashing, P.J., Gogarten, J.F., et al., 2020. Primates Can Be a Rallying Symbol to Promote Tropical Forest Restoration. Folia Primatol. 91, 669–687

Chazdon, R., Brancalion, P., 2019. Restoring forests as a means to many ends. Science 365, 24-25.

Dwivedi, A.K., Kumar, A., Baredar, P., Prakash, O., 2019. Bamboo as a complementary crop to address climate change and livelihoods – Insights from India. For. Policy Econ. 102, 66-74.

Embaye, K., 2000. The Indigenous Bamboo Forests of Ethiopia: An Overview. Ambio 29, 518-521.

Embaye, K., Weih, M., Ledin, S., Christersson, L., 2005. Biomass and nutrient distribution in a highland bamboo forest in southwest Ethiopia: implications for management. For. Ecol. Manage. 204, 159-169.

FAO, 2010. Global forest resources assessment 2010: Main report, edn. Food and Agriculture Organization of the United Nations, Forestry Department, Rome, Italy.

Garnett, S., Thomson, S., 2020. Are the implications for conservation of a major taxonomic revision of the world's birds' simply serendipity? Animal Conservation 23, 355-356.

Gibson, L., Lee, T.M., Koh, L.P., Brook, B.W., Gardner, T.A., Barlow, J., et al., 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature 478, 378.

Gippoliti, S., Butynski, T.M., Mekonnen, A., 2019. *Chlorocebus djamdjamensis.* The IUCN Red List of Threatened Species 2019: e.T4240A17958005. https://www.iucnredlist.org/ja/species/4240/17958005. Accessed 08 April 2021.

Gippoliti, S., 2020. Everything mammal conservation biologists always wanted to know about taxonomy (but were afraid to ask). J. Nat. Conserv. 54, 125793.

Green, S.J., Armstrong, J., Bogan, M., Darling, E., Kross, S., Rochman, C.M., et al., 2015. Conservation needs diverse values, approaches, and practitioners. Conserv. Lett. 8, 385-387.

Groves, C., 2005. Order Primates. In: Wilson, D.E., Reeder, D.M. (eds) Mammal species of the world: a taxonomic and geographic reference, vol 1. 3rd edn. Johns Hopkins University Press, Baltimore, MD, pp 111–184.

Haddad, N.M., Brudvig, L.A., Clobert, J., Davies, K.F., Gonzalez, A., Holt, R.D., et al., 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. Sci. Adv. 1, e1500052.

Hardin, I.R., Wilson, S.S., Dhandapani, R., Dhende, V., 2009. An assessment of the validity of claims for "Bamboo" fibers. AATCC review 9, 33-36.

Heller, N.E., Zavaleta, E.S., 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biol. Conserv. 142, 14-32.

IUCN, 2020. The IUCN Red List of Threatened Species: https://www.iucnredlist.org/. Accessed 20 December 2020.

Kalinkat, G., Cabral, J.S., Darwall, W., Ficetola, G.F., Fisher, J.L., Giling, D.P., et al., 2017. Flagship umbrella species needed for the conservation of overlooked aquatic biodiversity. Conserv. Biol. 31, 481-485.

Kaushal, R., Singh, I., Thapliyal, S.D., Gupta, A.K., Mandal, D., Tomar, J.M.S., et al., 2020. Rooting behaviour and soil properties in different bamboo species of Western Himalayan Foothills, India. Sci. Rep. 10, 4966.

Lewis, S.L., Wheeler, C.E., Mitchard, E.T., Koch, A., 2019. Regenerate natural forests to store carbon. Nature 568, 25-28.

Li, B.V., Pimm, S.L., 2016. China's endemic vertebrates sheltering under the protective umbrella of the giant panda. Conserv. Biol. 30, 329-339.

Liese, W., Köhl, M., 2015. Bamboo: the plant and its uses, edn. Springer, Heidelberg, Germany.

Ling, M., Christensen, M., Donnison, A., Belmonte, K.D., Brown, C., 2016. Scoping study to inform the Global Assessment of Bamboo and Rattan (GABAR), edn. UN Environment World Conservation Monitoring Centre, Cambridge, UK.

Lobovikov, M., Ball, L., Paudel, S., Guardia, M., Piazza, M., Russo, L., et al., 2007. World bamboo resources: a thematic study prepared in the framework of the global forest resources assessment 2005, edn. Food & Agriculture Org.

Lobovikov, M., Schoene, D., Lou, Y., 2012. Bamboo in climate change and rural livelihoods. Mitig. Adapt. Strateg. Glob. Chang. 17, 261-276.

Lu, H.-F., Cai, C.-J., Zeng, X.-S., Campbell, D.E., Fan, S.-H., Liu, G.-L., 2018. Bamboo vs. crops: An integrated emergy and economic evaluation of using bamboo to replace crops in south Sichuan Province, China. J. Clean. Prod. 177, 464-473.

MacDicken, K.G., 2015. Global forest resources assessment 2015: what, why and how? For. Ecol. Manage. 352, 3-8.

Macdonald, E.A., Hinks, A., Weiss, D.J., Dickman, A., Burnham, D., Sandom, C.J., et al., 2017. Identifying ambassador species for conservation marketing. Glob. Ecol. Conserv. 12, 204-214.

Manandhar, R., Kim, J.-H., Kim, J.-T., 2019. Environmental, social and economic sustainability of bamboo and bamboo-based construction materials in buildings. J. Asian Archit. Build. Eng. 18, 49-59.

McKenna, E. (2013). Ethiopia leads the bamboo revolution. *The Guardian*. Retrieved from https://www.theguardian.com/environment/2013/apr/10/ethopia-bamboo

Mekonnen, A., Bekele, A., Fashing, P.J., Hemson, G., Atickem, A., 2010a. Diet, activity patterns, and ranging ecology of the Bale monkey (*Chlorocebus djamdjamensis*) in Odobullu Forest, Ethiopia. Int. J. Primatol. 31, 339-362.

Mekonnen, A., Bekele, A., Hemson, G., Teshome, E., Atickem, A., 2010b. Population size and habitat preference of the Vulnerable Bale monkey *Chlorocebus djamdjamensis* in Odobullu Forest and its distribution across the Bale Mountains, Ethiopia. Oryx 44, 558-563.

Mekonnen, A., Bekele, A., Fashing, P.J., Lernould, J.-M., Atickem, A., Stenseth, N.C., 2012. Newly discovered Bale monkey populations in forest fragments in southern Ethiopia: Evidence of crop raiding, hybridization with grivets, and other conservation threats. Am. J. Primatol. 74, 423-432.

Mekonnen, A., Fashing, P.J., Bekele, A., Hernandez-Aguilar, R.A., Rueness, E.K., Nguyen, N., et al., 2017. Impacts of habitat loss and fragmentation on the activity budget, ranging ecology and habitat use of Bale monkeys (*Chlorocebus djamdjamensis*) in the southern Ethiopian Highlands. Am. J. Primatol. 79, e22644.

Mekonnen, A., Fashing, P.J., Bekele, A., Hernandez-Aguilar, R.A., Rueness, E.K., Stenseth, N.C., 2018a. Dietary flexibility of Bale monkeys (*Chlorocebus djamdjamensis*) in southern Ethiopia: Effects of habitat degradation and life in fragments. BMC Ecol. 18, 4.

Mekonnen, A., Fashing, P.J., Sargis, E.J., Venkataraman, V.V., Bekele, A., Hernandez-Aguilar, R.A., et al., 2018b. Flexibility in positional behavior, strata use, and substrate utilization among Bale monkeys (*Chlorocebus djamdjamensis*) in response to habitat fragmentation and degradation. Am. J. Primatol. 80, e22760.

Mekonnen, A., Rueness, E.K., Stenseth, N.C., Fashing, P.J., Bekele, A., Hernandez-Aguilar, R.A., et al., 2018c. Population genetic structure and evolutionary history of Bale monkeys (*Chlorocebus djamdjamensis*) in the southern Ethiopian Highlands. BMC Evol. Biol. 18, 106.

Mekonnen, A., Fashing, P.J., Bekele, A., Stenseth, N.C., 2020a. Distribution and conservation status of Boutourlini's blue monkey (*Cercopithecus mitis boutourlinii*), a Vulnerable subspecies endemic to western Ethiopia. Primates 61, 785–796.

Mekonnen, A., Fashing, P.J., Bekele, A., Stenseth, N.C., 2020b. Use of cultivated foods and matrix habitat by Bale monkeys in forest fragments: Assessing local human attitudes and perceptions. Am. J. Primatol. 82, e23074.

Mekonnen, A., Fashing, P.J., Venkataraman, V.V., Chapman, C.A., Stenseth, N.C., Hernandez-Aguilar, R.A., 2021. Sleeping site and tree selection by Bale monkeys (*Chlorocebus djamdjamensis*) at Kokosa forest fragment in southern Ethiopia. Int. J. Primatol.

Mekuriaw, Y., Urge, M., Animut, G., 2011. Role of indigenous bamboo species (*Yushania alpina* and *Oxytenanthera abyssinica*) as ruminant feed in northwestern Ethiopia. Livest. Res. Rural Dev. 23, 9.

Nath, A.J., Lal, R., Das, A.K., 2015. Managing woody bamboos for carbon farming and carbon trading. Glob. Ecol. Conserv. 3, 654-663.

Nath, A.J., Sileshi, G.W., Das, A.K., 2018. Bamboo based family forests offer opportunities for biomass production and carbon farming in North East India. Land Use Policy 75, 191-200.

Nayak, L., Mishra, S.P., 2016. Prospect of bamboo as a renewable textile fiber, historical overview, labeling, controversies and regulation. Fash. Text. 3, 2.

Newbold, T., Hudson, L.N., Hill, S.L., Contu, S., Lysenko, I., Senior, R.A., et al., 2015. Global effects of land use on local terrestrial biodiversity. Nature 520, 45-50.

Nitayaphat, W., Jiratumnukul, N., Charuchinda, S., Kittinaovarat, S., 2009. Mechanical properties of chitosan/bamboo charcoal composite films made with normal and surface oxidized charcoal. Carbohydr. Polym. 78, 444-448.

Nurse, E. (2016). Ethiopian bamboo: The new green gold of Africa? *CNN*. Retrieved from https://edition.cnn.com/2016/04/07/africa/ethiopia-bamboo-mpa/index.html

Partey, S.T., Sarfo, D.A., Frith, O., Kwaku, M., Thevathasan, N.V., 2017. Potentials of Bamboo-Based Agroforestry for Sustainable Development in Sub-Saharan Africa: A Review. Agric. Res. 6, 22-32.

Puri, V., Chakrabortty, P., Anand, S., Majumdar, S., 2017. Bamboo reinforced prefabricated wall panels for low cost housing. J. Build. Eng. 9, 52-59.

Rangel, T.F., Diniz-Filho, J.A.F., Bini, L.M., 2010. SAM: a comprehensive application for Spatial Analysis in Macroecology. Ecography 33, 46-50.

Roberge, J.M., Angelstam, P., 2004. Usefulness of the umbrella species concept as a conservation tool. Conserv. Biol. 18, 76-85.

Rodrigues, A.S., Brooks, T.M., 2007. Shortcuts for biodiversity conservation planning: the effectiveness of surrogates. Annu. Rev. Ecol. Evol. Syst. 38, 713-737.

Salzer, C., Wallbaum, H., Lopez, L.F., Kouyoumji, J.L., 2016. Sustainability of social housing in Asia: a holistic multi-perspective development process for bamboo-based construction in the Philippines. Sustainability 8, 151.

Satya, S., Singhal, P., Bal, L.M., Sudhakar, P., 2012. Bamboo shoot: a potential source of food security. Med. J. Nutrition Metab. 5, 1-10.

Sawarkar, A.D., Shrimankar, D.D., Kumar, A., Kumar, A., Singh, E., Singh, L., et al., 2020. Commercial clustering of sustainable bamboo species in India. Ind. Crops Prod. 154, 112693.

Schaller, G.B., 1985. Giant pandas of Wolong, edn. University of Chicago press, Chicago.

Scurlock, J.M., Dayton, D.C., Hames, B., 2000. Bamboo: an overlooked biomass resource? Biomass Bioenerg. 19, 229-244.

Shen, X., Li, S., McShea, W.J., Wang, D., Yu, J., Shi, X., et al., 2020. Effectiveness of management zoning designed for flagship species in protecting sympatric species. Conserv. Biol. 34, 158-167.

Simberloff, D., 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biol. Conserv. 83, 247-257.

Tefera, Z., Sillero-Zubiri, C., 2007. A flagship species for afroalpine conservation: an over view of the status and conservation of the Ethiopian wolf. Walia 25, 13-21.

Teshale, T., Woldeamanuel, T., Bekele, T., Alemu, A., Pretzsch, J., 2017. Market Channels for Highland Bamboo Poles Originated from Hula District, Sidama Zone Southern Ethiopia. Small-scale Forestry 16, 469-485.

Thornton, D., Zeller, K., Rondinini, C., Boitani, L., Crooks, K., Burdett, C., et al., 2016. Assessing the umbrella value of a range- wide conservation network for jaguars (*Panthera onca*). Ecol. Appl. 26, 1112-1124.

Trosvik, P., Rueness, E.K., de Muinck, E.J., Moges, A., Mekonnen, A., 2018. Ecological plasticity in the gastrointestinal microbiomes of Ethiopian *Chlorocebus* monkeys. Sci. Rep. 8, 20.

UN General Assembly, 2015. Transforming our world: the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1. https://www.refworld.org/docid/57b6e3e44.html. Accessed 21 November 2020.

Van Khuc, Q., Tran, B.Q., Meyfroidt, P., Paschke, M.W., 2018. Drivers of deforestation and forest degradation in Vietnam: An exploratory analysis at the national level. For. Policy Econ. 90, 128-141.

Ward, M., Rhodes, J.R., Watson, J.E.M., Lefevre, J., Atkinson, S., Possingham, H.P., 2020. Use of surrogate species to cost-effectively prioritize conservation actions. Conserv. Biol. 34, 600-610.

Weisse, M., Goldman, L., 2020. We lost a football pitch of primary rainforest every 6 seconds in 2019, edn. World Resources Institute, Washington, DC.

Yen, T.M., Lee, J.S., 2011. Comparing aboveground carbon sequestration between moso bamboo (*Phyllostachys heterocycla*) and China fir (*Cunninghamia lanceolata*) forests based on the allometric model. For. Ecol. Manage. 261, 995-1002.

Zhao, Y., Feng, D., Jayaraman, D., Belay, D., Sebrala, H., Ngugi, J., et al., 2018. Bamboo mapping of Ethiopia, Kenya and Uganda for the year 2016 using multi-temporal Landsat imagery. Int. J. Appl. Earth Obs. Geoinf. 66, 116-125.

Tables

Table 1. Selection criteria for the conservation of flagship and umbrella species.

Type	Description	Reference
Flagship species	Species that are taxonomically distinctive, threatened, and charismatic, which can serve as icons for conserving a particular habitat. They are usually selected based on socio-cultural factors, such as their ability to generate funding and to promote public awareness for implementing conservation activities.	Bowen-Jones and Entwistle (2002); Chapman et al. (2020); Kalinkat et al. (2017)
Umbrella species	Species with specific habitat requirements for which conservation actions (e.g., restoration and protection of their habitat) benefit many other sympatric species. They are often large wide-ranging species whose large area requirements conserve many other co-occurring species. However, small species with specific habitat requirements can also serve as umbrella species.	Roberge and Angelstam (2004); Caro (2010); Thornton et al. (2016); Ward et al. (2020)
Flagship-umbrella species	A species that can serve both as a flagship and an umbrella species	Caro (2010)

Table 2. Summary of the number of taxa in each conservation category and with range overlap with the Bale monkey.

Description	Mammals	Birds	Amphibians	Reptiles	Total animal	Vascular plants
Total number of species in Ethiopia	271	821	72	242	1406	6,603
Number of endemic and/or threatened species	66	46	11	5	128	518
Number (and %) of endemic species	**45 (16.6%)**	**20 (2.4%)**	**11 (15.3%)**	**4 (1.7)**	**80 (6.1%)**	**489 (7.4%)**
Critically Endangered	2	1	3	0	6	10
Endangered	7	2	3	0	12	17
Vulnerable	8	7	3	0	18	11
Near Threatened	4	2	1	1	8	5
Least Concern	15	8	1	3	27	13
Data Deficient	9	0	0	0	9	8
Not Evaluated by IUCN	-	-	-	-	-	425
Number (and %) of threatened species	**38 (14.0%)**	**36 (4.4%)**	**9 (12.5%)**	**1 (0.4%)**	**84 (6.0%)**	**60 (1.0%)**
Critically Endangered	3	7	3	0	13	10
Endangered	14	8	3	0	25	25
Vulnerable	21	21	3	1	46	25
Endemic species that have range overlap with Bale monkey range	16	6	7	2	31	7
Number of threatened species that have range overlap with Bale monkey range	12	18	6	0	36	3
No. of endemic and/or threatened species that have range overlap with Bale monkey range	20	23	7	2	52	9
Number of both endemic and threatened species that have range overlap with Bale monkey range	8	1	6	0	15	1
Number of threatened species that have forest habitat overlap with Bale monkey	9	7	6	0	22	1
Number of endemic species that have forest habitat overlap with Bale monkey	8	2	7	2	19	4
Number of endemic and/or threatened species that have forest habitat overlap with Bale monkey	12	9	7	2	30	5

Number of both endemic and threatened species that have forest habitat overlap with Bale monkey	5	0	6	0	11	1

NA: No available data for most endemic species of plants on their distribution, abundance, ecology and status in the current IUCN Red List.

Table 3. List of endemic and/or threatened terrestrial animal species whose ranges overlap with that of the Bale monkey.

No.	Scientific name	English name	Taxon	Category	IUCN Red List status	Threatened status	Endemicity	Elevation (m)	Forest habitat overlap	Habitat
1	*Tragelaphus buxtoni*	Mountain nyala	Mammal	Herbivorus mammal - Large	EN	Yes	Yes	1800 - 4300	Yes	Forest, Grassland, Shrubland
2	*Tachyoryctes macrocephalus*	Giant Mole Rat	Mammal	Small mammal (Rodent)	EN	Yes	Yes	3000 - 4150	No	Grassland
3	*Megadendromus nikolausi*	Nikolaus's mouse	Mammal	Small mammal (Rodent)	VU	Yes	Yes	3000 - 3800	No	Shrubland
4	*Lophuromys melanonyx*	Black-clawed Brush-furred Rat	Mammal	Small mammal (Rodent)	VU	Yes	Yes	3100 - 4300	Yes	Artificial/Terrestrial, Grassland, Forest
5	*Crocidura lucina*	Lucina's Shrew	Mammal	Small mammal (Shrew)	VU	Yes	Yes	3000 - 4050	No	Wetlands (inland), Grassland
6	*Crocidura harenna*	Harenna shrew	Mammal	Small mammal (Shrew)	CR	Yes	Yes	2400 - 2630	Yes	Forest
7	*Crocidura bottegoides*	Bale shrew	Mammal	Small mammal (Shrew)	EN	Yes	Yes	2400 - 3280	Yes	Forest, Grassland
8	*Myotis scotti*	Scott's mouse-eared bat	Mammal	Bat	VU	Yes	Yes	1300 - 2500	Yes	Shrubland, Forest
9	*Cyanochen cyanoptera*	Blue-winged Goose	Bird	Bird	VU	Yes	Yes	1800 - 4100	No	Grassland, Wetlands, Shrubland
10	*Leptopelis ragazzii*	Shoa Forest Treefrog	Amphibia	Amphibia	VU	Yes	Yes	1930 - 3010	Yes	Artificial/Terrestrial, Wetlands, Forest
11	*Ericabatrachus baleensis*	Bale Mountains Frog	Amphibia	Amphibia	CR	Yes	Yes	2400 - 3200	Yes	Forest, Wetlands
12	*Balebreviceps hillmani*	Bale Mountains Treefrog	Amphibia	Amphibia	CR	Yes	Yes	2815 - 3200	Yes	Shrubland, Forest
13	*Altiphrynoides osgoodi*	Osgood's Ethiopian Toad	Amphibia	Amphibia	CR	Yes	Yes	1950 - 3520	Yes	Wetlands, Shrubland, Forest
14	*Altiphrynoides malcolmi*	Malcolm's Ethiopia Toad	Amphibia	Amphibia	EN	Yes	Yes	2500 - 4000	Yes	Artificial/Terrestrial, Shrubland, Forest
15	*Afrixalus enseticola*	Ethiopian Banana Frog	Amphibia	Amphibia	VU	Yes	Yes	1700 - 2750	Yes	Forest, Wetlands, Artificial/ Terrestrial, Grassland
16	*Lepus starcki*	Ethiopian Highland Hare	Mammal	Herbivorus mammal - Medium	LC	No	Yes	2140 - 4380	No	Artificial/Terrestrial, Grassland, Shrubland
17	*Stenocephalemys griseicauda*	Gray-tailed narrow-headed rat	Mammal	Small mammal (Rodent)	LC	No	Yes	2400 - 3900	No	Grassland, Shrubland
18	*Stenocephalemys albocaudata*	Ethiopian narrow-headed rat	Mammal	Small mammal (Rodent)	LC	No	Yes	3000 - 4377	No	Grassland, Shrubland
19	*Stenocephalemys albipes*	Ethiopian white-footed mouse	Mammal	Small mammal (Rodent)	LC	No	Yes	800 - 3300	Yes	Artificial/Terrestrial, Shrubland, Forest

20	*Lophuromys chrysopus*	Ethiopian forest brush-furred rat	Mammal	Small mammal (Rodent)	LC	No	Yes	1200 - 2760	Yes	Forest
21	*Arvicanthis blicki*	Blick's Grass Rat	Mammal	Small mammal (Rodent)	NT	No	Yes	2500 - 4050	No	Grassland
22	*Crocidura thalia*	Thalia's shrew	Mammal	Small mammal (Shrew)	LC	No	Yes	515 - 3300	Yes	Wetlands, Grassland, Shrubland, Savanna, Forest
23	*Crocidura glassi*	Glass's shrew	Mammal	Small mammal (Shrew)	NT	No	Yes	2700 - 4050	No	Wetlands, Grassland, Shrubland
24	*Vanellus melanocephalus*	Spot-breasted Lapwing	Bird	Bird	LC	No	Yes	1800 - 4100	No	Artificial/Terrestrial, Wetlands, Grassland
25	*Serinus nigriceps*	Ethiopian Siskin	Bird	Bird	LC	No	Yes	1800 - 4100	No	Grassland, Shrubland
26	*Poicephalus flavifrons*	Yellow-fronted Parrot	Bird	Bird	LC	No	Yes	300 - 3200	Yes	Artificial/Terrestrial, Savanna, Forest
27	*Parophasma galinieri*	Abyssinian Catbird	Bird	Bird	LC	No	Yes	2440 - 3,655	Yes	Forest, Artificial/ Terrestrial, Shrubland
28	*Macronyx flavicollis*	Abyssinian Longclaw	Bird	Bird	NT	No	Yes	1200 - 3000	No	Grassland
29	*Trioceros harennae*	Harenna Hornless Chameleon	Reptile	Reptile	LC	No	Yes	2400 - 3300	Yes	Forest, Shrubland, Artificial/Terrestrial
30	*Trioceros balebicornutus*	Bale Two-horned Chameleon	Reptile	Reptile	NT	No	Yes	1500 - 2400	Yes	Forest
31	*Ptychadena erlangeri*	Erlanger's Grassland Frog	Amphibia	Amphibia	NT	No	Yes	1300 - 2500	Yes	Wetlands, Grassland, Forest
32	*Lycaon pictus*	African wild dog	Mammal	Carnivorous mammal	EN	Yes	No	0 - 4000	Yes	Forest, Savanna, Shrubland, Grassland, Desert
33	*Panthera leo*	Lion	Mammal	Carnivorous mammal	VU	Yes	No	0 - 4200	Yes	Forest, Savanna, Shrubland, Grassland, Desert
34	*Panthera pardus*	Leopard	Mammal	Carnivorous mammal	VU	Yes	No	0 - 5200	Yes	Forest, Savanna, Shrubland, Grassland, Rocky areas, Desert
35	*Otomops harrisoni*	Harrison's large-eared giant mastiff bat	Mammal	Bat	VU	Yes	No	Unknown	Yes	Artificial/Terrestrial, Savanna, Forest
36	*Trigonoceps occipitalis*	White-headed Vulture	Bird	Bird	CR	Yes	No	Unknown - 4000	No	Artificial/Terrestrial, Grassland, Shrubland, Savanna
37	*Torgos tracheliotos*	Lappet-faced Vulture	Bird	Bird	EN	Yes	No	Unknown - 3500	Yes	Savanna, Grassland, Desert, Shrubland, Forest
38	*Streptopelia turtur*	European Turtle-dove	Bird	Bird	VU	Yes	No	Unknown - 1300	Yes	Forest, Shrubland, Artificial/Terrestrial
39	*Sagittarius serpentarius*	Secretarybird	Bird	Bird	VU	Yes	No	Unknown	No	Artificial/Terrestrial, Grassland, Shrubland, Savanna
40	*Polemaetus bellicosus*	Martial Eagle	Bird	Bird	VU	Yes	No	0 - 3000	Yes	Savanna, Wetlands, Grassland, Shrubland, Forest

41	*Neophron percnopterus*	Egyptian Vulture	Bird	Bird	EN	Yes	No	0 - 4500	No	Rocky areas, Artificial/Terrestrial, Wetlands, Grassland, Shrubland, Savanna
42	*Necrosyrtes monachus*	Hooded Vulture	Bird	Bird	CR	Yes	No	0 - 4000	Yes	Artificial/Terrestrial, Desert, Grassland, Shrubland, Savanna, Forest
43	*Gyps rueppelli*	Rüppell's Vulture	Bird	Bird	CR	Yes	No	0 - 4500	No	Rocky areas, Desert, Grassland, Shrubland, Savanna
44	*Gyps africanus*	White-backed Vulture	Bird	Bird	CR	Yes	No	0 - 3500	Yes	Artificial/Terrestrial, Desert, Grassland, Shrubland, Savanna, Forest
45	*Falco cherrug*	Saker Falcon	Bird	Bird	EN	Yes	No	0 - 4700	No	Wetlands, Artificial/Terrestrial, Grassland, Shrubland
46	*Bugeranus carunculatus*	Wattled Crane	Bird	Bird	VU	Yes	No	2000 - 4140	No	Artificial/Aquatic & Marine, Artificial/ Terrestrial, Wetlands, Grassland
47	*Bucorvus abyssinicus*	Northern Ground-hornbill	Bird	Bird	VU	Yes	No	Unknown - 3227	Yes	Savanna, Shrubland, Rocky areas, Grassland, Forest
48	*Balearica pavonina*	Black Crowned Crane	Bird	Bird	VU	Yes	No	Unknown	No	Artificial/Terrestrial, Marine, Coastal/ Supratidal, Wetlands, Grassland, Savanna
49	*Aythya ferina*	Common Pochard	Bird	Bird	VU	Yes	No	Unknown	No	Artificial/Aquatic & Marine, Marine Coastal/Supratidal, Marine Neritic, Wetlands (inland)
50	*Aquila rapax*	Tawny Eagle	Bird	Bird	VU	Yes	No	0 - 3000	Yes	Savanna, Shrubland, Artificial/Terrestrial, Grassland, Forest
51	*Aquila nipalensis*	Steppe Eagle	Bird	Bird	EN	Yes	No	0 - 3000	No	Savanna, Grassland, Rocky areas
52	*Acrocephalus griseldis*	Basra Reed-warbler	Bird	Bird	EN	Yes	No	1500 - 7000	No	Shrubland, Artificial/ Aquatic & Marine, Wetlands, Savanna

IUCN Red List status: Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Evaluated (NE)
Threatened status: Yes: if the species is either VU, EN or CR; No: if the species is either LC or NT; Unknown (UN): if the species is classified as DD; and NE: if the species is not yet evaluated by IUCN
Endemicity: Yes if the species is exclusively found within Ethiopia's political boundaries and No: if the species found in another country
Forest habitat overlap: Yes: if the species uses forest habitat and No: if the species does not use forest habitat; Unknown: if data is not available
Endemic species: No. 1-31; threatened species: No. 1-15, 32-52

Table 4. List of threatened and/or endemic vascular plant species whose ranges overlap with that of the Bale monkey.

No	Scientific name	Family	Growth form	Phylum	Taxon	IUCN Red List status	Threatened status	Endemicity	Elevation (m)	Forest habitat overlap	Habitat
1	*Trifolium schimperi*	Fabaceae	Herb	Tracheophyta	Dicotyledons	LC	No	Yes	1700 - 3150	No	Grassland
2	*Urtica simensis*	Urticaceae	Herb	Tracheophyta	Dicotyledons	NE	UN	Yes	Unknown	Yes	Forest
3	*Mikaniopsis clematoides*	Asteraceae	Herb	Tracheophyta	Dicotyledons	NE	UN	Yes	Unknown	Yes	Forest
4	*Aloe welmelensis*	Asphodelaceae	Shrub	Anthophyta	Monocotyledons	DD	UN	Yes	1050 - 1500	No	Rocky areas
5	*Vepris dainellii*	Rutaceae	Shrub	Tracheophyta	Dicotyledons	LC	No	Yes	1750-2500	Yes	Forest
6	*Erythrina brucei*	Fabaceae	Tree	Tracheophyta	Dicotyledons	LC	No	Yes	1400-2600	Yes	Forest
7	*Eriocaulon aethiopicum*	Eriocaulaceae	Herb	Tracheophyta	Monocotyledons	VU	Yes	Yes	Unknown	No	Wetlands (inland)
8	*Aloe rugosifolia*	Asphodelaceae	Shrub	Anthophyta	Monocotyledons	VU	Yes	No	1000 - 1800	No	Savanna
9	*Prunus africana*	Rosaceae	Tree	Tracheophyta	Dicotyledons	VU	Yes	No	Unknown	Yes	Forest

IUCN Red List status: Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Evaluated (NE)
Threatened status: Yes: if the species is either VU, EN or CR; No: if the species is either LC or NT; Unknown (UN): if the species is classified as DD; and NE: if the species is not yet evaluated by IUCN
Endemicity: Yes if the species is exclusively found within Ethiopia's political boundaries and No: if the species is found in another country
Forest habitat overlap: Yes: if the species uses forest habitat and No: if the species does not use forest habitat

Figure legends

Fig. 1. Geographical range and localities of Bale monkeys in the southern Ethiopian Highlands, including the Bale Mountains National Park (BMNP).

Fig. 2 Bale monkeys are visually striking animals that live in bamboo forests that people in high-income countries know little about. These traits combined with the fact that primates often receive special attention in fund raising efforts, means that they can serve as a flagship species, bringing global attention to the need to conserve them and their bamboo habitat. Photo by Nik Borrow.

Fig. 3. Species richness maps of terrestrial animal species, including mammals, birds, reptiles, and amphibians, that occur in Ethiopia. (a) Richness of threatened species (Vulnerable, Endangered or Critically Endangered in the IUCN Red List), (b) Richness of endemic species, (c) Richness of endemic and/or threatened species, and (d) Richness of all terrestrial animal species found in Ethiopia.

Fig. 4. Phenomenological model showing the interdependence of Bale monkey and bamboo conservation as well as the significance of Bale monkey conservation to achieving sustainable development goals (SDGs).

Fig. 5. Sidama traditional home made from bamboo at Arbegona, Sidama Region, southern Ethiopia. Photo by Addisu Mekonnen.

Fig. 1

Click here to access/download;Figure;Fig. 1.jpg

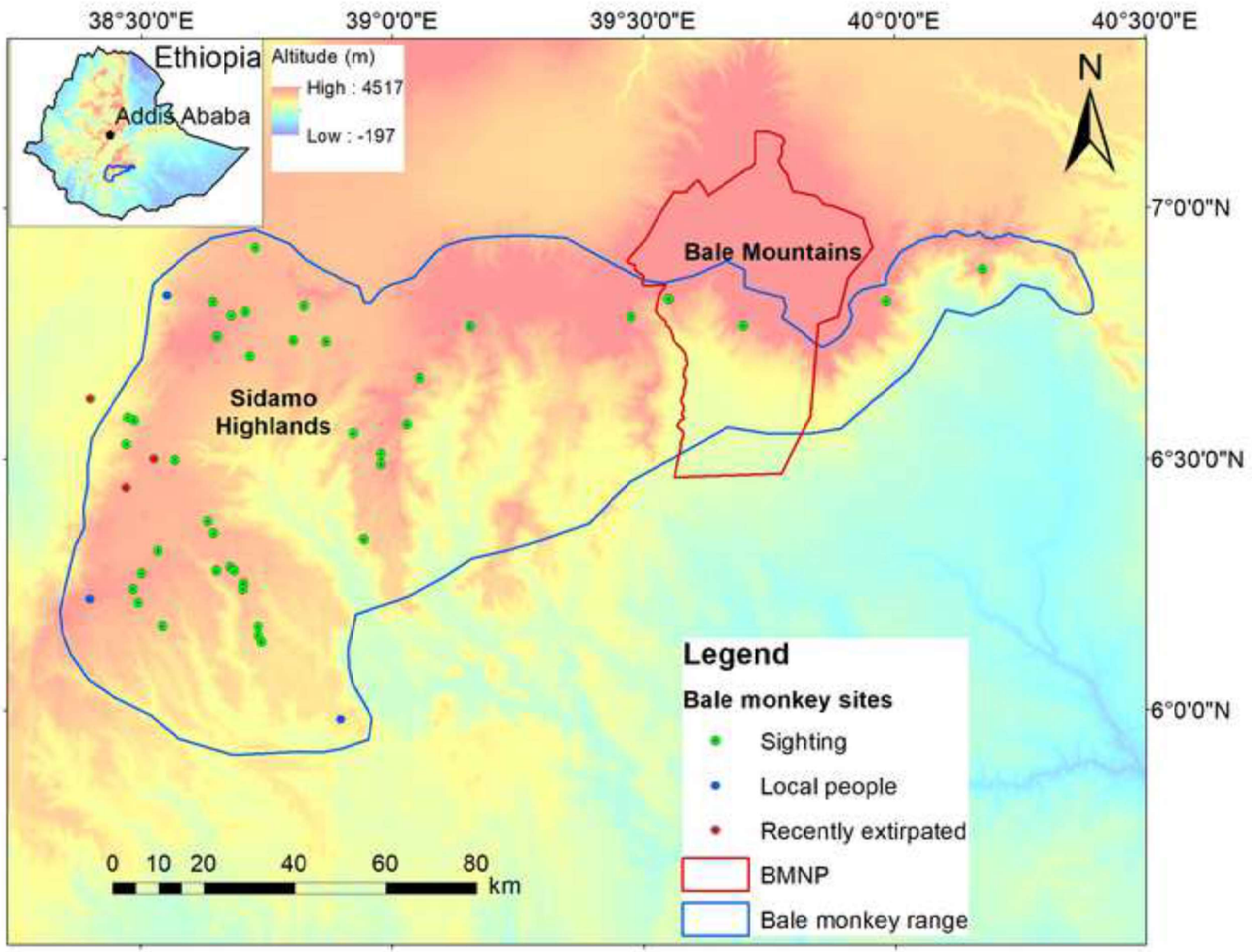

Fig. 2

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Fig. 3

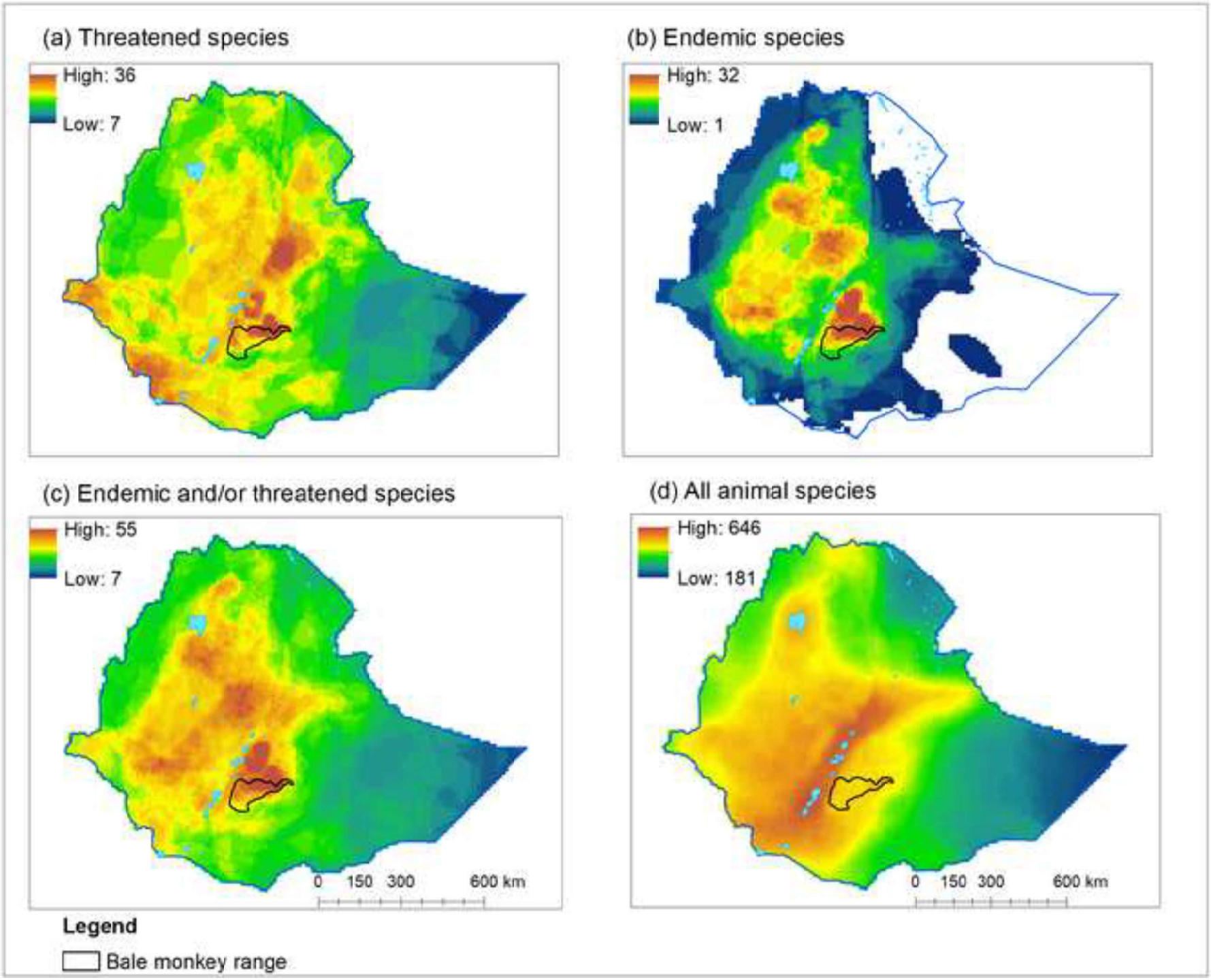

Fig. 4

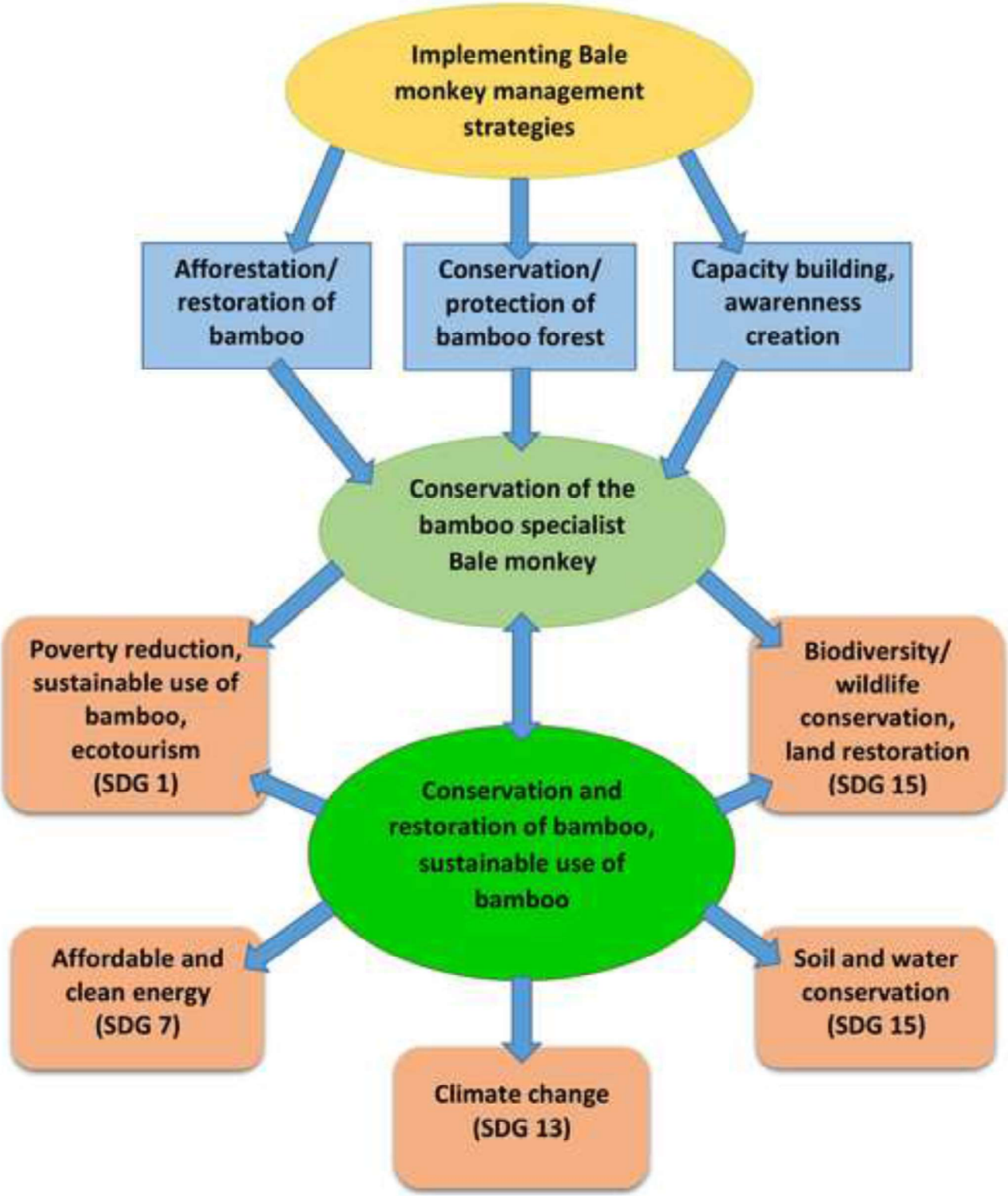

Fig. 5

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Declaration of Competing Interests

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