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Gone with the forest: Assessing global woodpecker conservation from land use patterns

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Abstract

Aim: As a result of their ecological traits, woodpeckers (Picidae, Aves) are highly sensitive to forest cover change. We explored the current land cover in areas of high species richness of woodpeckers to determinate regions where urgent conservation actions are needed. In addition, we identified woodpecker species that are sensitive to forest loss and that have high levels of human habitat modification and low levels of protection (through protected areas) in their distribution ranges.

Location: Global.

Methods: We joined available range maps for all extant 254 woodpecker species with information of their conservation status and tolerances to human habitat modifications and generated a richness map of woodpecker species worldwide. Then, we associated this information (the richness pattern and individual species' maps) with land cover and protected areas (PAs) maps.

Result: We found that the foremost woodpecker species richness hotspot is in Southeast Asia and is highly modified. At the second species richness hotspot in the eastern Andes, we observed a front of deforestation at its southern extreme and a greater deforested area in its northern extreme but most of its area remains with forest coverage. At the species level, 17 species that are sensitive to forest modification experience extensive deforestation and have low extents of PAs in their ranges.

Main conclusions: The most diverse woodpecker hotspots are mostly occupied by human-modified landscapes, and a large portion of the species there avoids anthropogenic environments. The level of representation of woodpecker species in PAs is low as a global general pattern, although slightly better in Asia. Our global analysis of threats to woodpecker from land use patterns reiterates the urgent conservation needs for Southeast Asian forests. Finally, based on our results, we recommend a re-evaluation for inclusion in the Red List of five woodpecker species.

KEYWORDS
Aichi targets, deforestation, human-modified habitats, logging, protected areas, Red List

1 | INTRODUCTION

Forest ecosystems host approximately two-thirds of the global land biodiversity (SCBC 2010) and are facing several threats. The main threat is the clearing of forests for agriculture, followed by urbanization, resulting in forest loss and fragmentation (Brooks et al., 2002; Hansen et al., 2013; Laurance et al., 2012). These land use changes result in threats to biodiversity of virtually all taxonomic groups (Fischer, & Lindenmayer, 2007; Foley, 2005; Sala et al., 2000). Although land use change is ongoing since historical times, worryingly, rates of change during the 20th century and early 21st century are the highest in human history (Goldewijk, 2001; Hansen et al., 2013). Land use change dynamics are spatially and temporally heterogeneous at the global scale. In North America and Europe, for example, forest conversion processes were rapid in the 19th century but have since declined, whereas in South America, Southeast Asia and western Africa, conversion rates were high during the 20th century, and continue to increase at present (Goldewijk, 2001; Hansen et al., 2013). Considering that tropical and subtropical forests are the major reservoirs of biodiversity globally, the current rates of deforestation that affect these biomes are of great concern (Gibson et al., 2011; Laurance et al., 2012).

Many bird species are particularly sensitive to forest cover change, and habitat modification generates a reduction in species abundance, richness and diversity (Bregman, Şekercioğlu, & Tobias, 2014; Radford, Bennett, & Cheers, 2005; Şekercioğlu, 2002). Some groups are particularly sensitive to forest cover change because of their ecological traits. Woodpeckers (Picidae) are mainly restricted to forested areas, with only a few species adapted to treeless landscapes, resulting in a clear association of this family with forest environments (Mikusiński, 2006). Indeed, at broad scales, woodpecker species richness is strongly related with forest cover (Ilsøe, Kissling, Fjeldså, Sandel, & Svenning, 2017). The dependence of woodpeckers on forest habitats results from their foraging on and into tree trunks, branches and fallen logs, and their excavation of roost and nest cavities, often in large, old and (partly) dead trees. These ecological traits together with other attributes such as sedentariness and poor dispersal in most species (Mikusiński, 2006) result in woodpeckers being a group highly sensitive to forest cover change (Henle, Davies, Kleyer, Margules, & Settele, 2004; Ilsøe et al., 2017; Virkkala, 2006). Some woodpecker species are capable of maintaining populations in managed forests or in tree plantations, but even these species usually reach higher densities in extensive, natural forest areas (Lammertink, 2014; Winkler & Christie, 2017). Because of the strong association between traits of woodpeckers and forests environments (Ilsøe et al., 2017), woodpeckers have been used in the guiding of forest management and of forest biodiversity conservation (Lammertink, 2004; Nilsson, Hedin, & Niklasson, 2001; Uliczka, Angelstam, Roberge, & Uliczka, 2004; Virkkala, 2006).

Through their excavating habits, woodpeckers benefit other species. For example, the nest and roost cavities made by woodpeckers are used for shelter and nesting by many vertebrate and insect species. Woodpeckers positively affect the abundance and richness of cavity-nesting birds (Drever, Aitken, Norris, & Martin, 2008; Martin & Eadie, 1999; Ruggera, Schaaf, Vivanco, Politi, & Rivera, 2016). Finally, the sap wells made by some woodpeckers are an important source of sugars for other species (Blendinger, 1999; Daily, Ehrlich, & Haddad, 1993; Kitching & Tozer, 2010; Montellano, Blendinger, & Macchi, 2013). These various roles of woodpeckers justify their use as indicators for forest health, especially for forest birds (Drever et al., 2008; Gao, Nielsen, & Hedblom, 2015; Kumar et al., 2011; Mikusiński, Gromadzki, & Chylarecki, 2001; Virkkala, 2006).

The family Picidae contains approximately 254 species (del Hoyo & Collar, 2014) and has a cosmopolitan distribution with the exceptions of Madagascar, New Guinea, Australia and Antarctica (Winkler & Christie, 2017). Woodpecker richness tends to be lower at higher latitudes, and geographic range size decreases in areas with high woodpeckers species richness (Blackburn, Gaston, & Lawton, 2008). From mapping analyses, Mikusiński (2006) and Winkler (2015) identified two regions as species richness hotspots with at least 15 species present regionally, in south-eastern Asia and northern and central parts of South America. These woodpecker hotspots are located in economically developing countries: Thailand, Myanmar, Vietnam, Cambodia and Indonesia in Asia; and Colombia, Peru, Ecuador, Brazil and Suriname in South America. The ecological requirements of woodpeckers inhabiting the hotspots often remain unclear, and until now, there has been no attempt to evaluate the proportion of their original range overlapping with human-modified landscapes and with protected areas.

For woodpeckers and forest biodiversity in general, protected areas (PAs) networks should ensure the survival and viability of populations of species threatened by forest loss and degradation (Rodrigues, Akçakaya, et al., 2004; Rodrigues, Andelman, et al., 2004). However, historically, the allocation of PAs has not been based on biodiversity distribution patterns, but instead on economic criteria, such as low land productivity, or scenic beauty (Devillers et al., 2015; Nori et al., 2016; Pressey, Whish, Barrett, & Watts, 2002). Consequently, often PAs do not adequately include biodiversity, with the most important gaps in areas suitable for intensive human uses (Nori et al., 2015; Pimm et al., 2014; Watson, Dudley, Segan, & Hockings, 2014). Considering that woodpecker species richness is highest in tropical and subtropical regions that are suitable for agricultural production (Mikusiński, 2006), it can be expected that many woodpecker species are poorly represented in PAs. Woodpeckers species richness is strongly related to regional forest cover (Ilsøe et al., 2017), and it is important to determinate the areas of high species richness that are being subjected to high forest loss rates, as these may well be strategic areas where urgent conservation actions are needed to ensure the conservation of woodpeckers.

Given the association between woodpeckers and well-conserved forest, and the empathy that the group generates in human populations (Arango, Rozzi, Massardo, Anderson, & Ibarra, 2007; Cocker, 2013), the family is suited to be used in conservation planning. Such use may for instance aid in meeting the objectives of the Strategic Plan for Biodiversity 2011–2020 of the 10th United Nations Convention on Biological Diversity Conference of the Parties. The Parties made the commitment to conserve adequately at least 17% of terrestrial surface of the world, paying particular attention to vulnerable areas (Butchart et al., 2015).

In this study, we aim to provide a global picture of the degree of protection and human-induced change inside the distributional extent of each woodpecker species worldwide, in order to identify especially vulnerable areas and species for which conservation actions are imperative. In particular, we aim to: (1) explore the current land cover in areas of high species richness of woodpeckers; (2) determine the overlap between the range of each woodpecker species and human-modified areas; (3) determine the overlap between the range of each woodpecker species and PAs; (4) identify those species with a high proportion of their ranges in human-modified areas, low degree of land protection and sensitive to human-induced change of their habitats (following Winkler & Christie, 2017); and (5) re-evaluate the previous objective for restricted-range species.

2 | METHODS

2.1 | Data

We downloaded available digital range maps for all extant or possibly recently extinct 254 woodpeckers species in the BirdLife International and NatureServe Database (www.birdlife.org). Using the spatial join tool of ArcGIS 10.3, we associated with each range the conservation status of the species and its recent population trend (IUCN, 2014). Additionally, using the same software, we calculated the surface of the range of each species. Although the global scale of our analyses implies the need to assume some level of commission and omission errors in species distribution when using range maps, these maps satisfactorily represent the known distribution of most of the species included and are appropriate for global analyses (Ficetola, Bonardi, Mücher, Gilissen, & Padoa-Schioppa, 2014).

We obtained shapefiles of terrestrial protected areas (PAs) around the globe from the World Database on Protected Areas website (IUCN & UNEP, 2015). We selected only those protected areas with the "designated" status (i.e., we did not consider "inscribed," "non-reported," nor "proposed" protected areas) from I to IV management categories defined by the IUCN (i.e., categories which have specific conservation objectives), totalling 71,097 protected areas. Using the spatial analyse toolbox of ArcGIS, we calculated the percentage of each species' distribution which overlapping with PAs.

We downloaded a global land cover map for the year 2015 with a resolution of 300 m (http://www.esa-landcover-cci.org/). We reclassified this raster map into a binary one discriminating those areas occupied by crops (i.e., pixels with at least 50% of their surface occupied by crops) and urban settlements, from all the other categories.

2.2 | Data analysis

By overlapping the binary raster map of land cover with the range of each species, using the tabulate area tool of ArcGIS, we calculated the surface and percentage of each range occupied by human-modified landscapes. Additionally, using the "lets.presab" function of R package (R Core Team, 2014) letsR (Vilela & Villalobos, 2015) and IUCN range maps, we generated a binary presence–absence raster for each species at spatial resolution of 0.5 degrees, and then, by adding these individual maps, a raster of richness of woodpeckers species at the same spatial resolution was created. We overlapped this map of species richness with the binary raster of human-modified landscapes, generating a bivariate global map, to obtain the maximum expected species richness, in human-modified landscapes. Using this bivariate map, we determined where those areas of high expected richness overlapped with human-modified landscapes.

Finally, using the "select by attributes" function of ArcGIS 10.3, we selected those species with more than 60% of their ranges overlapping with human-modified areas, and less than 10% of their ranges inside PAs. While the selection of the threshold of 60% for human-modified area was subjective, it was chosen considering that only 15% of all woodpecker species fall under this threshold. We follow the criterion proposed by Rodrigues, Akçakaya, et al. (2004) and Rodrigues, Andelman, et al. (2004) of a minimal representation of 10% of the range for each broadly distributed species inside PAs in order for the species to be considered covered, considering that most of woodpecker species have a medium-to-large distributional range of more than 100,000 km^2. The selected species, on the basis of the above criteria, were reclassified as tolerant or sensitive to human habitat modifications following Winkler and Christie (2017), a source that is frequently updated with peer-reviewed publications. We consider as sensitive, those species which only inhabit well-preserved forest; conversely, we considered as tolerant those species able to inhabit highly modified areas (key words: cultivated lands, plantations, coconut plantations, coffee plantations, gardens, wooded gardens, degraded forests, parks, cane fields, palm groves, orchards and burnt forest). We used the same function of ArcGIS 10.3 to estimate human-modified and protected areas for restricted-range woodpecker species, that is, with geographic ranges less than 50,000 km^2.

3 | RESULTS

Several anthropized areas overlapped with high woodpeckers species richness (between 15 and 23 species; Figure 1). The brightest hotspots were in continental Southeast Asia and the Sundaland archipelago. In particular, central Myanmar, Isthmus of Kra in Thailand and Myanmar, and Sumatra have human-modified areas with the occurrence of 20–23 woodpeckers species, the human-modified areas with the highest values of woodpecker richness in the world. Scattered and small spots approaching this species richness were identified in southern Vietnam, Cambodia, near the Nepal–India border and on the island of Borneo. The second hotspot identified was a large human-modified region in the central-east of South America, in Atlantic Forest and Cerrado biomes where between 11 and 14 woodpecker species co-occur. Moreover, we identified some smaller areas near the coast of Brazil and near the border between Bolivia and Brazil with values of between 15 and 19 woodpecker species. A woodpecker richness hotspot in the northern Andes with between 15 and 20 species remains largely intact, although we identified human-modified areas within this hotspot in western Colombia. Finally, a small area in Central Africa shows human-modified areas with 11–19 woodpecker species. In the same region, we identified some areas with more than 15 woodpecker species in well-conserved areas (Figure 1).

Regarding representation in PAs, and the proportion of human-modified areas overlapping with ranges of woodpecker species (Figure 2), we found that Asia is the continent with the highest levels

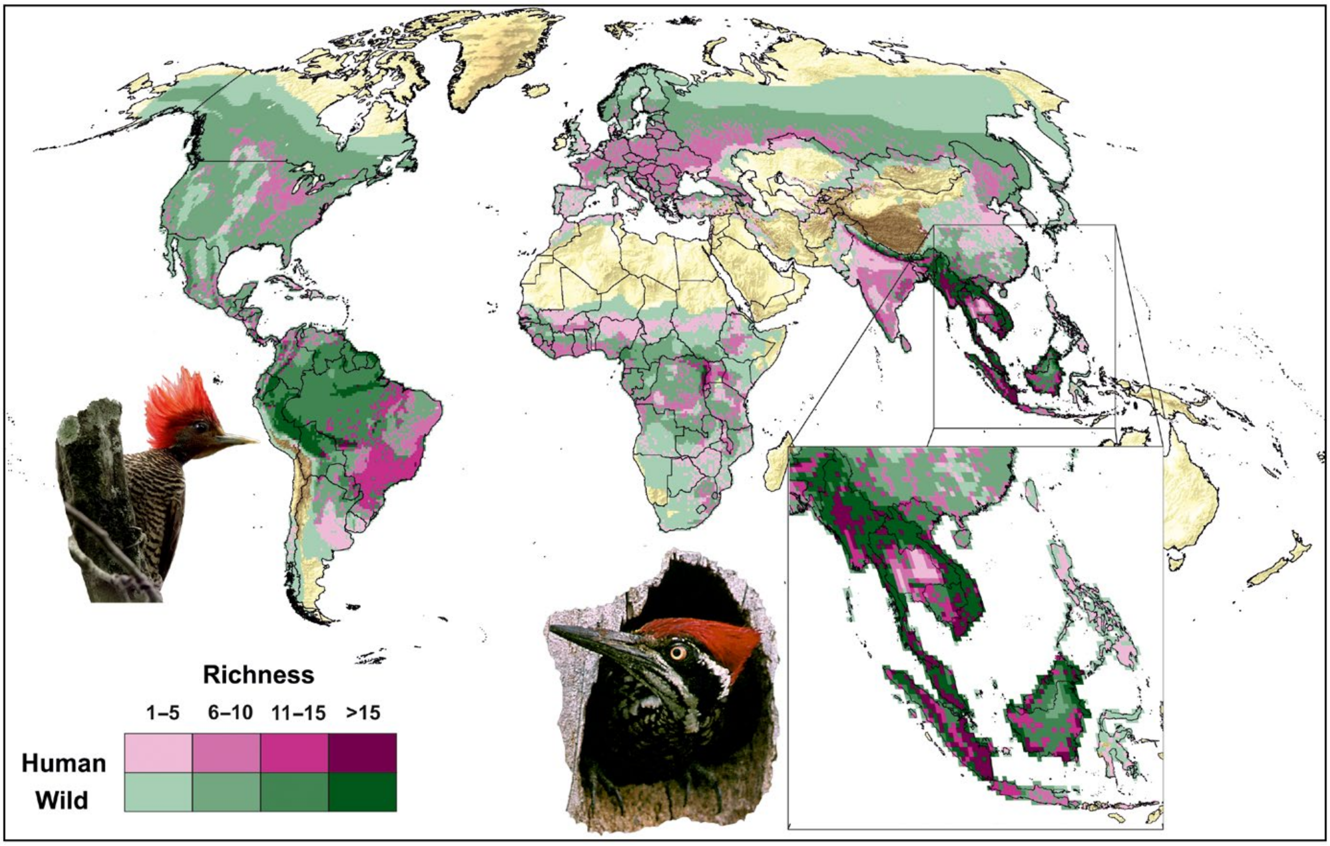

FIGURE 1 Maximum expected woodpecker species richness map. Green gradient indicates non-human-modified areas; purple gradient indicates human-modified areas (intensive agriculture and urban areas). Darker areas indicate greater richness for both colour gradients. Photograph insects: Helmeted Woodpecker from South America and Greater Flameback from Southeast Asia

of human-modified areas overlapping with woodpecker distributions: 41.8% of the species ranges in Asia are within human-modified landscapes. Counterbalancing this, in Asia, there is also the highest representation, of 8.5%, of woodpecker distributions inside PAs. In contrast, Europe and North America show low levels of human-modified areas and low levels of protected areas. In South America, 7.3% of species distributions are within protected areas, scoring second in that measure after Asia. Human-dominated areas in South America overlapped with 22.3% of woodpecker distributions. Africa had the second highest level of human-modified areas after Asia, but also had a higher percentage of protected areas overlapping with woodpecker distributions than Europe and North America.

Regarding woodpecker species with more than 60% of their ranges overlapping with human-modified areas and less than 10% of their ranges represented in PAs, we found three such species in Africa (5% of species on this continent), 12 species in South America (13%) and 23 species in Asia (28%) (Figures 3 and 4a). All three of these species in Africa are sensitive to human habitat modification, seven of these species are sensitive in South America (58%), and seven are sensitive in Asia (30%; Figure 5). Nevertheless, most of the species with this profile (large overlap with highly modified areas, little overlap with protected areas and sensitive to human habitat modification), currently are in the Least Concern category of the IUCN Red List: that is, 5 of 7 in South America, 3 of 3 in Africa and 4 of 7 in Asia (Figure 5).

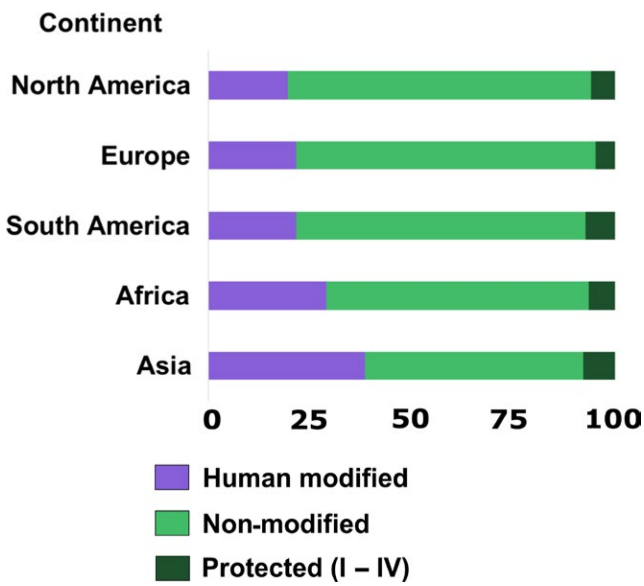

FIGURE 2 Bars indicate the mean percentage of human-modified area (purple), protected (dark green) and non-modified area (light green) of all woodpeckers species present in each continent

We found a high variability in the percentage of human-modified area among restricted-range species (Figure 6). While some of these species have large percentages of their ranges in unaltered areas,

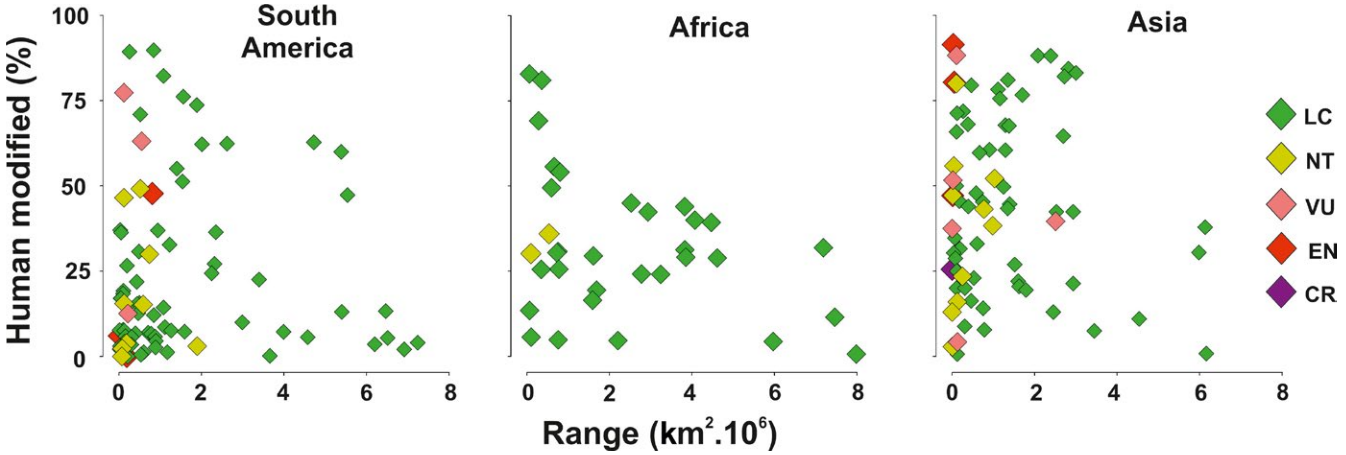

FIGURE 3 Dot graphics for three continents (South America, Africa and Asia) where we identified woodpeckers species with high proportions of human-modified areas (intensive agriculture and urban areas) in their distribution ranges. Each dot represents a woodpecker species and its colour indicates the conservation status. The dot position is defined by the woodpeckers range extension (horizontal axis) and the percentage of its distribution overlapping with human-modified areas (vertical axis)

others, such as Yellow-faced Woodpecker (*Chrysocolaptes xanthocephalus*) and White-rumped Woodpecker (*Meiglyptes tristis*), have alarming percentages of human-modified areas in their ranges of over 80%. In general, the observed patterns of land modification and protection in restricted-range species are in reasonable accordance with their current threat categorization by IUCN. The percentages of human-modified area, protected area and non-modified area for each woodpecker species are included in the Appendix S1.

4 | DISCUSSION

This is a first global assessment of woodpecker conservation combining the ranges of species, their conservation status and ecological disturbance tolerance, the spatial pattern of human modification of the landscape and the distribution of PAs. Regrettably, the emerging picture is worrisome: the most diverse woodpecker hotspots, located in Southeast Asia, are mostly occupied by human-modified landscapes, and a large portion of the species there avoids anthropogenic environments. The level of representation of woodpecker species in PAs is low as a global general pattern, although slightly better in Asia. The advance of agricultural frontier in Southeast Asia is rapid (Hansen et al., 2013; Miettinen, Shi, & Liew, 2011), and this will inevitably have strong negative effects on woodpeckers species (Ilsøe et al., 2017). The forests of Southeast Asia have been identified before as a conservation hotspot for their rich biodiversity and rapid and extensive deforestation (Sodhi et al., 2010; Tilman et al., 2017; Tracewski et al., 2016). Our global analysis of threats to woodpecker from land use patterns reiterates the urgent conservation needs for Southeast Asian forests.

The next important woodpecker species richness hotspot, located in and near the eastern Andes of South America (Mikusiński, 2006; Figure 1), shows a different, more encouraging pattern. Areas of high woodpecker species richness there did not show a strong overlap with human-modified landscapes. The topographic characteristics and low degree of human development spare parts of the region from intensive agricultural practices (Olson et al., 2001). This hotspot represents an area of high irreplaceability, but low vulnerability as of yet (Margules & Sarkar, 2000). Even so, deforestation has been making inroads in this hotspot between 2000 and 2015, in central and southern Peru, northwest Bolivia and the Brazilian state of Acre (Hansen et al., 2013). In South America, six of seven species with profiles of low representation in protected areas and with most of their original habitats anthropized occur away from Andean and Amazonian species richness hotspots (Figure 5). Instead, they occur in Atlantic Forest, Cerrado and Caatinga habitats, where the agricultural frontier is progressing rapidly (Grecchi, Beuchle, Shimabukuro, Sano, & Achard, 2015; Ribeiro, Metzger, Martensen, Ponzoni, & Hirota, 2009).

The representation of the ranges of woodpecker species in PAs is low: on average 6.78% of the ranges of species, with the lowest value of 4.99% in Europe. This is especially problematic in Asia and Africa, where the overlap between woodpecker ranges and human-modified landscapes shows the highest values: 41.8% and 31.0% for Asia and Africa, respectively. In addition, the agricultural frontier in most countries of these continents is advancing rapidly (Goldewijk, 2001; Hansen et al., 2013; Miettinen et al., 2011), reducing the extent of the forest habitats that are obligatory for most woodpecker species.

For individual species, we identified 17 species that met the profile of avoiding human-modified landscapes, and having over 60% of human-modified land and less than 10% of protected land in their ranges (Figure 5). Of these, one is currently in the IUCN Near-Threatened category, three are in the Vulnerable category, and one is in the Endangered category. The remaining 12 are currently in the Least Concern category, in several cases questionably so. Although our threat profiles do not directly correspond to IUCN criteria (for instance, a reduction in the global population of over 30% in 10 years or three generations to enter IUCN Vulnerable status), our threat profiles may signal species that are in more or less trouble than currently

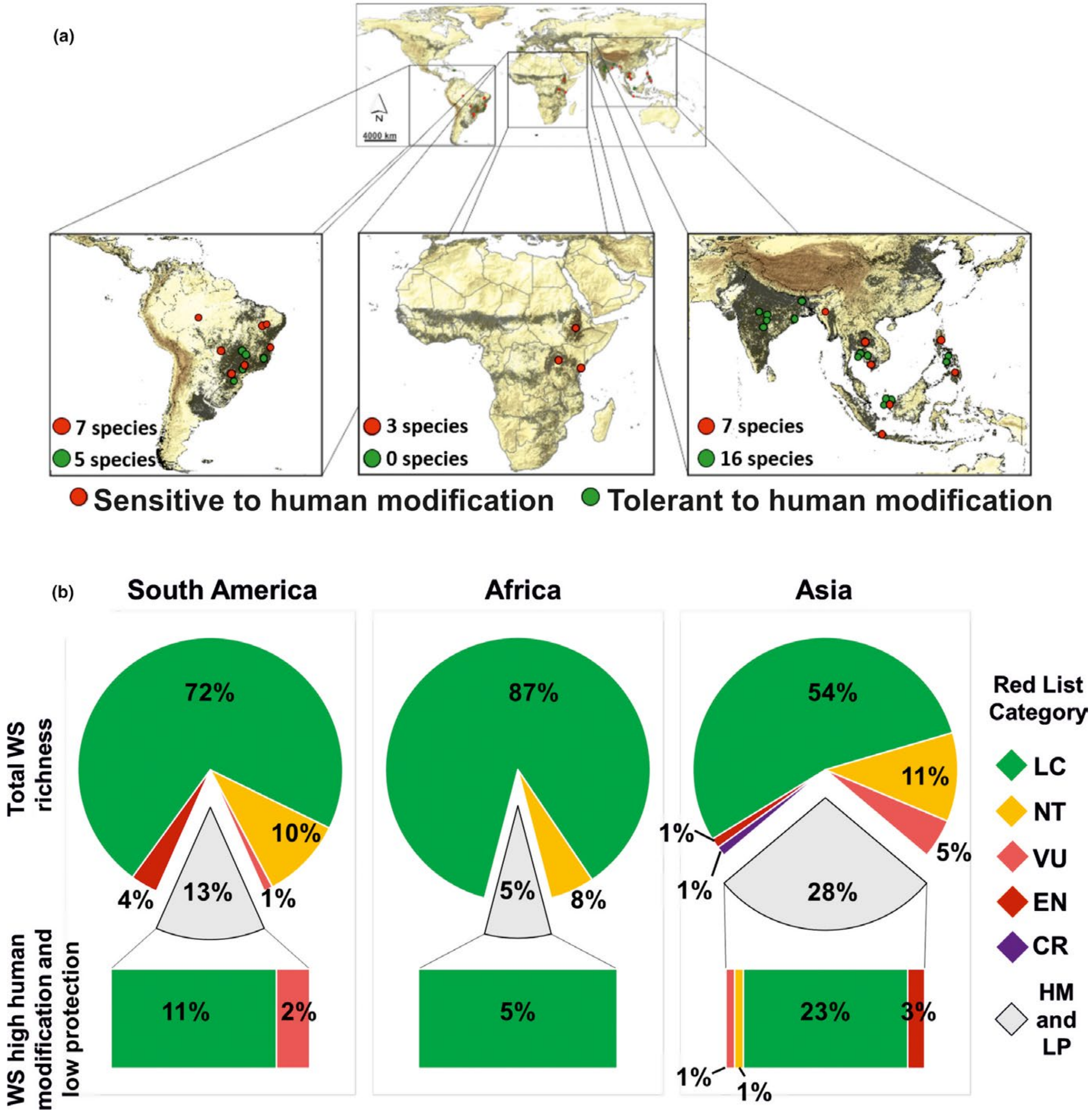

FIGURE 4 Identified woodpecker species (WS) that experience high levels of human modification and low protection in their ranges. (a) Three continents where we identified species considering these criteria. Points indicate centroids of the distributions of identified species, in red for species sensitive to human modifications and in green for species tolerant to human modifications. In addition, grey shadows on the map indicate human-modified areas (intensive agriculture and urban areas). (b) Circular graphics show the percentage of species per Red List category (IUCN) by continent, and a portion in light grey indicates the percentage of woodpeckers species with high human-modified area and low protection in its range extension. Lower bars show the percentages of species per Red List category with human-modified distributions and low protection (HM and LP)

recognized by IUCN. In South America, we point to the profiles in Figure 5 of Ochre-backed Woodpecker (*Celeus ochraceus*) and Spotted Piculet (*Picumnus pygmaeus*) that indicate a more precarious situation than that of two species on the continent that are on the IUCN Red List. In Africa, the situations of Fine-banded Woodpecker (*Campethera taeniolaema*), Abyssinian Woodpecker (*Dendropicos abyssinicus*) and Mombasa Woodpecker (*Campethera mombassica*) similarly ask for re-evaluation of their threat status, as these obligate natural forest species have between 64% and 82% of their ranges currently anthropized, and only between 3% and 10% of their ranges in protected areas. We

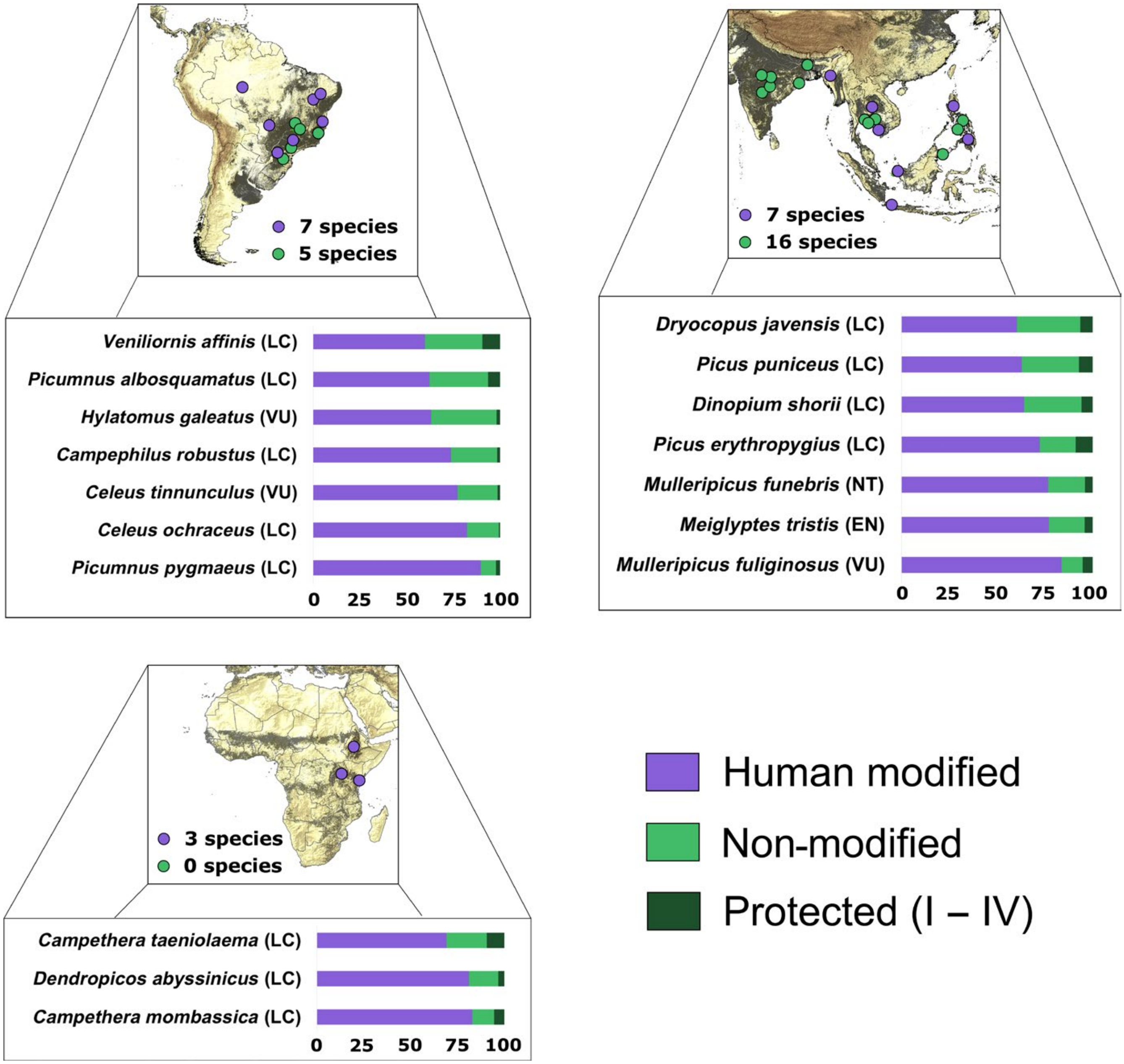

FIGURE 5 Land use percentages in the ranges of woodpecker species sensitive to human habitat modification (following Winkler & Christie, 2017). Bars show the percentage of human-modified habitat (purple), protected area (dark green) and non-modified area (light green) in the distribution ranges. The shown woodpecker species were selected based on having over 60% of human-modified land in their ranges and less than 10% of protected land in their ranges. IUCN conservation status is indicated in parenthesis

recommend a re-evaluation of the status of these species through the BirdLife International Globally Threatened Birds consultation forum. In Asia, on the other hand, there is a good match between IUCN Red List status and the threat profiles in Figure 5. The three Asian species with the highest threat profiles in Figure 5 are already considered as threatened or near-threatened by IUCN, and the four Asian species with lower threat profiles are in the IUCN Least Concern category. It is of importance to note that several of these identified species have been recently recognized as distinct species. For example, Ochre-backed Woodpecker and Fine-banded Woodpecker have been recently split as distinct species from Blond-crested Woodpecker (*Celeus flavescens*) and Tullberg's Woodpecker (*Campethera tullbergi*), respectively. The taxonomic change in these species led us to identify the threats that these woodpeckers experience. Given that these are recently recognized species, it is important to develop more research on their habitat affinities and population trends to evaluate whether the patterns that we observed represent a serious threat.

The levels of representation in PAs of range-restricted species seem to follow a random pattern (Figure 6). This is similar to findings for most vertebrate groups (Nori et al., 2015; Rodrigues, Akçakaya, et al., 2004; Rodrigues, Andelman, et al., 2004). In fact, range-restricted species have not been historically a criterion for PAs selection. Reserves are

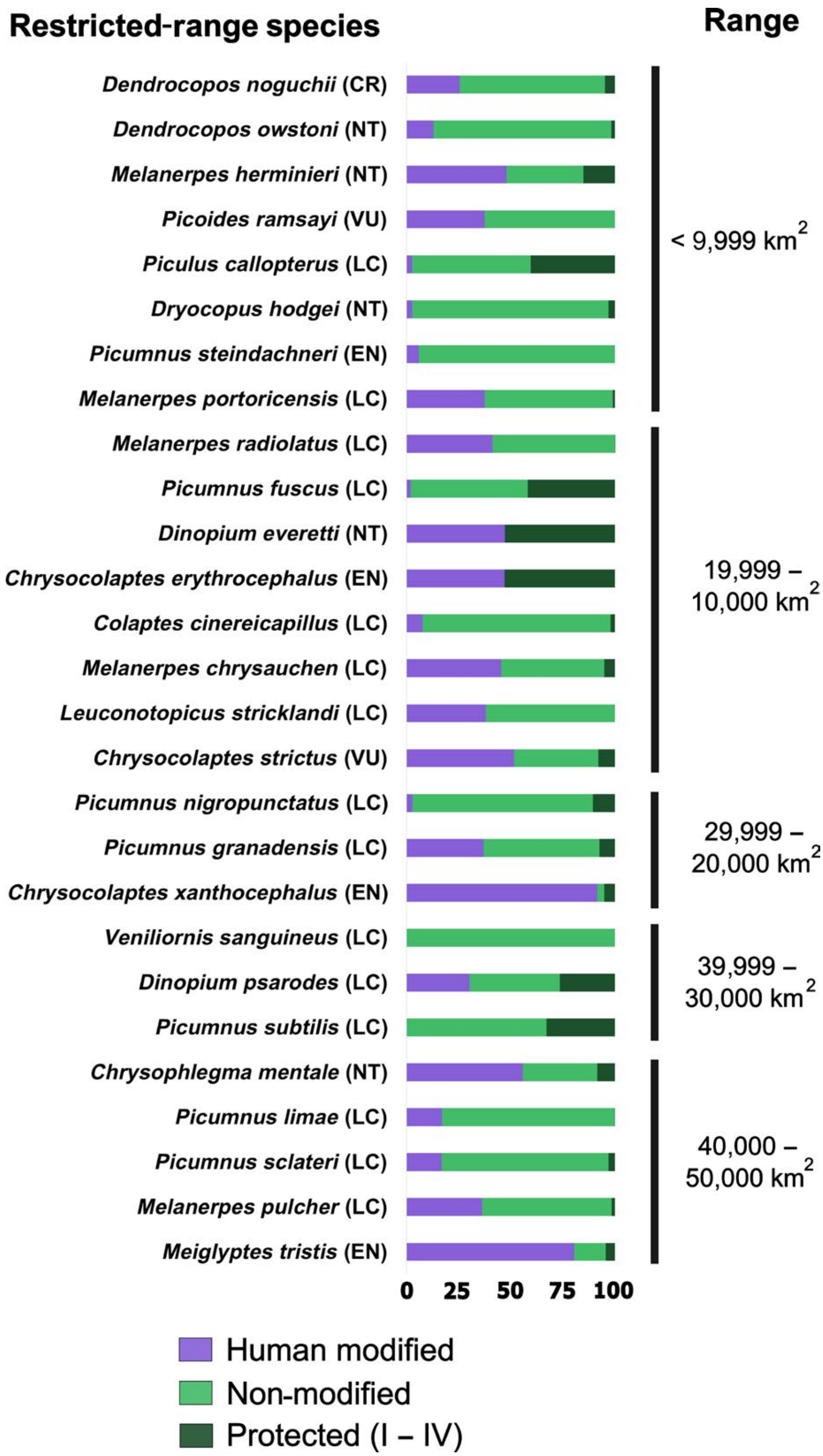

FIGURE 6 Land use percentages in the distributions of restricted-range woodpecker species. Bars show the percentage of human-modified habitat (purple), protected area (dark green) and non-modified area (light green) in the distribution ranges. Species are ordered by increasing range extension. IUCN conservation status is indicated in parenthesis

typically located in residual places where the potential for extractive uses is low (Devillers et al., 2015; Pressey, Visconti, & Ferraro, 2015). The dominantly residual nature of PAs is one reason why species continue to go extinct, even when most countries have increased the number and extent of established PAs over the past 10 years (Watson et al., 2014). This scenario is threatening for those species inhabiting productive environments. Restricted ranges, in synergy with a low representation in PAs, large percentages of habitats occupied by human-modified environments and an active agricultural frontier, could lead to new extinction events. Among the woodpeckers of the world, 27 species have restricted ranges of under 50.000 km^2 (Figure 6). Of these, seven are considered threatened by IUCN and five are considered near-threatened. The remaining 15 are currently in the IUCN Least Concern category. Of those, there are seven species with over 30% or over 40% of their ranges anthropized, that is, Greyish Piculet (*Picumnus granadensis*), Puerto Rican Woodpecker (*Melanerpes portoricensis*), Jamaican Woodpecker (*Melanerpes radiolatus*), Golden-naped Woodpecker (*Melanerpes chrysauchen*), Beautiful Woodpecker (*Melanerpes pulcher*) and Strickland's Woodpecker (*Leuconotopicus stricklandi*). The *Melanerpes* and *Picumnus* species of this list are generally tolerant to habitat modification, as long as some tree cover remains, and their status may not be as precarious as the land use species profiles indicate. The Strickland's Woodpecker is more of an obligate forest species, and it has no protected areas in its range. It may be approaching near-threatened status. The Okinawa Woodpecker (*Dendrocopos noguchii*) has 75% of its range remaining in forest, with 5% in protected areas. Both percentages are positive signals, but more information about occupancy and habitat requirement of this species is needed to re-evaluate its IUCN Critically Endangered status.

Lack of biological knowledge has been identified as one of the most important shortfalls for biodiversity conservation (Bini, Diniz-Filho, Rangel, Bastos, & Pinto, 2006; Diniz-Filho, Loyola, Raia, Mooers, & Bini, 2013; Hortal et al., 2015). Studies on woodpecker biology and/or ecology in South America, Africa and Southeast Asia are scarce compared to Europe and North America (Lammertink, 2014; Mikusiński, 2006). Studies assessing the ecological response to land use changes, and assessing population trends, of the woodpecker species we identified above as potentially requiring a threat category change are needed to more accurately determine their conservation status. Until these gaps are filled, precautionary measures are recommendable, as those recently suggested by Jarić, Courchamp, Gessner, & Roberts, 2016, Jetz & Freckleton, 2015 and Trindade-Filho et al., 2012.

In our presentation of a global picture of the conservation status of woodpeckers, there are shortfalls that we acknowledge, most of them associated with the scale of the analyses, the source of the data and the lack of essential information. For example, habitat requirements for large woodpeckers species such as old trees with large stem diameters (for nesting, roosting and foraging; Aitken & Martin, 2007; Lammertink et al., 2009) or habitat connectivity (Roberge, Angelstam, & Villard, 2008) result in these species being more vulnerable than other woodpeckers species. Given that our analysis only identified urban and deforested areas and did not include other categories such as forests with selective logging, or forest plantations, we underestimated the habitat loss of species with special habitat requirements. On the other hand, our assignation of human-modified landscapes as unsuitable for woodpeckers is also crude, as several woodpecker species may persist in traditional or older agricultural landscapes with scattered trees and woodlots, whereas recent industrial-scale land clearance will leave no habitat for woodpeckers. In addition, it is important to note that in some regions, such as tropical regions of Africa, Asia and South America, PAs are not sufficiently effective in halting deforestation (Heino et al., 2015). This could lead to an overestimation of the levels of protection provided by PAs and consequently generate an even worse picture than that estimated here for many key species. Finally, our binary categorization of tolerant and sensitive species is crude because it does not consider species that tolerate intermediate levels of forest disturbance. Our approach possibly excludes some species sensitive to certain kind of disturbances. A next step would be to evaluate separately the conservation status for each woodpecker identified based on our analysis as having a large portion of their range modified, combined with detailed species-specific habitat requirements, if this information is available. It is possible that this approach would identify other threatened species with intermediate levels of tolerance to human disturbances not recovered in our analysis.

The range maps provided by IUCN (2015) we worked with may have inaccuracies, but are considered to suffice for analyses at large spatial scales (Ficetola et al., 2013). We combined these maps with a fine resolution raster of land cover (300 m). Inaccuracies of range maps could lead to bias in the estimations of the percentages of the distributions overlapping (and not overlapping) with human-dominated areas, for some species. This problem would especially affect the assessments of range-restricted species, as a small area could represent a large percentage of the distribution. Fortunately, most woodpecker identified as "major concern" species here are relatively widely distributed, so this problem could only marginally affect the estimated pattern for them. Regarding land cover maps, it is important to note that our analyses were performed only with current information (2015; http://www.esa-landcover-cci.org/). While this is a suitable way to generate a current picture of the conservation of the group, we point out that the inclusion of additional information regarding land cover change over time would be helpful to approximate population trends. We recommend for future studies the inclusion of land use change data in an analysis of woodpecker conservation trends.

In this work, we have pinpointed several problems and opportunities at an opportune moment. The area of PAs is globally increasing (Watson et al., 2014) to reach Aichi Targets (Butchart et al., 2015), and decision-makers in consultation with the scientific community are working to achieve these targets as accurately as possible by determining "areas of particular importance for biodiversity and ecosystem services" (Di Minin et al., 2016; Kukkala & Moilanen, 2016; Montesino Pouzols et al., 2014; Tracewski et al., 2016). Our work from the perspective of the woodpeckers as denizens of the world's forests is a contribution to help achieve this task. Due to their roles in community structuration, clear habitat requirements and strong positive relationship with well-conserved forest (e.g., Ilsøe et al., 2017; Ruggera et al., 2016), woodpeckers should be strongly considered for use as a focal or surrogate group in conservation planning of wooded areas (Hermoso, Januchowski-Hartley, & Pressey, 2013). Our results highlight hotspots of woodpecker richness of South America and central Africa, which have as yet low levels of land conversion. These are important regions to implement conservation actions. In addition, the woodpecker hotspot of south-eastern Asia presents a remarkable level of deforestation but relatively high representation in PAs. Conservation actions in this region should take into account the biggest remaining forested areas and increase their efficiency, by providing connectivity through reforestation and the restoration of formerly logged areas to mature conditions.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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