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3 **Conservation attention necessary across at least 44% of Earth's** 4 **terrestrial area to safeguard biodiversity**

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6 **Abbreviated Title:** Land area needed to conserve biodiversity

7 **Authors**

8 James R. Allan^{*1,2,3}, Hugh P. Possingham^{2,4}, Scott C. Atkinson^{2,5}, Anthony
9 Waldron⁶, Moreno Di Marco^{7,8}, Vanessa M. Adams⁹, Stuart H. M. Butchart^{10,11},
10 Oscar Venter¹², Martine Maron^{2,8}, Brooke A. Williams^{2,8}, Kendall R. Jones¹³, Piero
11 Visconti¹⁴, Brendan A. Wintle¹⁵, April E. Reside^{2,8}, James E.M. Watson^{2,8,13}

12 **Affiliations**

13 ¹School of Biological Sciences, University of Queensland, St Lucia QLD 4072, Australia

14 ²Centre for Biodiversity and Conservation Science, The University of Queensland, St Lucia, QLD
15 4072, Australia

16 ³Institute for Biodiversity and Ecosystem Dynamics (IBED), University of Amsterdam, P.O. Box 94240,
17 1090 GE, Amsterdam, The Netherlands

18 ⁴The Nature Conservancy, VA 22203-1606, USA

19 ⁵United Nations Development Programme (UNDP), New York, New York, USA

20 ⁶Cambridge Conservation Initiative, David Attenborough Building, Department of Zoology, Cambridge
21 University, Cambridge CB2 3QZ, UK

22 ⁷Department of Biology and Biotechnologies, Sapienza University of Rome, viale dell'Università 32, I-
23 00185 Rome, Italy

24 ⁸School of Earth and Environmental Sciences, The University of Queensland, St Lucia QLD 4072,
25 Australia

26 ⁹School of Technology, Environments & Design, University of Tasmania, Hobart, TAS 7001, Australia

27 ¹⁰BirdLife International, David Attenborough Building, Pembroke Street, Cambridge CB2 3QZ, UK.

28 ¹¹Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK.

29 ¹²Natural Resource and Environmental Studies Institute, University of Northern British Columbia,
30 Prince George, V2N4Z9, Canada

31 ¹³Wildlife Conservation Society, Global Conservation Program, 2300 Southern Boulevard, Bronx, NY
32 10460-1068, USA

33 ¹⁴International Institute for Applied System Analyses, Schlossplatz 1, A-2361 Laxenburg, Austria

34 ¹⁵School of BioSciences, University of Melbourne, Vic., Australia

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36 **Keywords** Conservation, Aichi Targets, Protected Areas, Prioritisation, Conservation
37 Planning, Restoration, Threatened Species, Strategic Plan for Biodiversity,
38 Convention on Biological Diversity, Terrestrial biodiversity.

39 *Correspondence to: James R. Allan. E-mail: James.allan@uqconnect.edu.au

40 **More ambitious conservation efforts are needed to stop the global degradation**
41 **of ecosystems and the extinction of the species that comprise them. Here, we**
42 **estimate the minimum amount of land needed to secure known important sites**
43 **for biodiversity, Earth's remaining wilderness, and the optimal locations for**
44 **adequate representation of terrestrial species distributions and ecoregions. We**
45 **discover that at least 64 million km² (43.6% of Earth's terrestrial area) requires**
46 **conservation attention either through site-scale interventions (e.g. protected**
47 **areas) or landscape-scale responses (e.g. land-use policies). Spatially explicit**
48 **land-use scenarios show that 1.2 million km² of land requiring conservation**
49 **attention is projected to be lost to intensive human land-use by 2030 and**
50 **therefore requires immediate protection. Nations, local communities and**
51 **industry are urged to implement the actions necessary to safeguard the land**
52 **areas critical for conserving biodiversity.**

53 Conserving natural areas is crucial for safeguarding biodiversity and Earth system
54 processes¹, and is central to the Convention on Biological Diversity (CBD)'s 2050
55 vision of sustaining a healthy planet and delivering benefits essential for all people².
56 The current CBD Aichi Target 11 aims to protect at least 17% of land area by 2020³,
57 but this is widely seen as inadequate for halting biodiversity declines and averting the
58 extinction crisis⁴⁻⁶. Post-2020 target discussions are now well underway⁷, and there is
59 a broad consensus that the amount of land and sea being set aside for conservation
60 attention must increase⁸. Recent calls are for targets to conserve anywhere from 26
61 to 60% of land and ocean area by 2030 through site-scale responses such as
62 protected areas and 'other effective area-based conservation measures' (OECMs)⁹⁻¹³.
63 But there is increasing recognition that site-scale responses must be supplemented
64 by broader landscape-scale actions aimed at halting vegetation destruction¹⁴. Global
65 conservation targets are set by intergovernmental negotiation, but scientific input is
66 essential to provide evidence about the location and amount of land necessary to
67 conserve biodiversity.

68 Several broad scientific approaches exist that help provide evidence for global
69 conservation, but when used in isolation, potentially provide conflicting or confusing
70 evidence. For example, there are efficiency-based planning approaches that focus on
71 maximising the number of species or ecosystems captured within a complementary
72 set of conservation areas, prioritising species and ecosystems by their endemism,
73 extinction risk, the degree to which they are represented (or underrepresented) in
74 existing protected areas, or other criteria^{15,16}. There are also site-based approaches
75 such as the Key Biodiversity Area (KBA) initiative¹⁷, which aims to identify significant
76 sites for biodiversity persistence using criteria including in relation to occurrence of
77 threatened or geographically restricted species or ecosystems, intact ecological
78 communities, or important biological processes (e.g. breeding aggregations)¹⁷. There
79 are also proactive approaches that aim to conserve the last places that are free from
80 human pressure, sometimes called 'wilderness areas'¹⁸, before they are eroded.
81 These areas are increasingly recognised as essential for Earth system functioning¹⁹,
82 sustaining long-term ecological and evolutionary processes²⁰ and long-term species
83 persistence²¹, especially under climate change²². Examples include boreal forests
84 which hold one-third of the world's terrestrial carbon and many wide-ranging
85 species^{23,24}, and the Amazon rainforest which needs to be maintained in its entirety,

86 not just its most species-rich areas, for it to sustain continent-scale hydrological
87 patterns²⁵.

88 Although all these approaches and initiatives are complementary and provide
89 essential evidence needed to set biodiversity conservation targets, the adoption of any
90 one of them as a unique guide for decision-making is likely to omit potentially critical
91 elements of the CBD vision²⁶. For example, a species-based focus on identifying areas
92 in a way that most efficiently captures the most species would fail to recognise the
93 Earth-system importance of the Boreal or Amazon forests, or the critical need to
94 maintain large intact ecosystems globally for biodiversity²¹. Equally, a focus on
95 proactively conserving Earth's intact ecosystems would fail to achieve representation
96 of some of Earth's species or ecosystems²⁷. Put simply, all approaches will lead to
97 partly overlapping but often distinct science-based suggestions for area-based
98 conservation²⁸. Rather than debating the merits of any individual approach, we
99 suggest that achieving the CBD vision requires a unified global strategy that
100 comprehensively conserves species and ecosystems as well as Earth's remaining
101 intact ecosystems, and we provide a methodological framework that utilises all three
102 approaches.

103 Here, we identify the minimum land area requiring conservation attention
104 globally. We start from the basis of existing protected areas (PAs), KBAs, and
105 wilderness areas, and then efficiently add a large enough fraction of the ranges of
106 28,594 species of mammals, birds, amphibians, reptiles, dragonflies and crustaceans
107 to enable their persistence^{15,16,29}, while also capturing representative samples of all
108 terrestrial ecoregions³⁰. We are not suggesting that all of this land should be
109 designated as protected areas. Rather, we argue that it should be managed through
110 a range of strategies for species and ecosystem conservation. For example, extensive
111 areas that are remote and unlikely to be converted for human uses in the near-term
112 could be safeguarded through effective sustainable land-use policies, while some
113 locations may be best conserved through OECMs³¹ rather than formal protected
114 areas. We believe the appropriate governance and management regimes for any area
115 depends in part on the likelihood of its habitat being converted to human uses³² or
116 degraded by human pressures³³, and as such, the response for conserving the areas
117 we identify will be context specific.

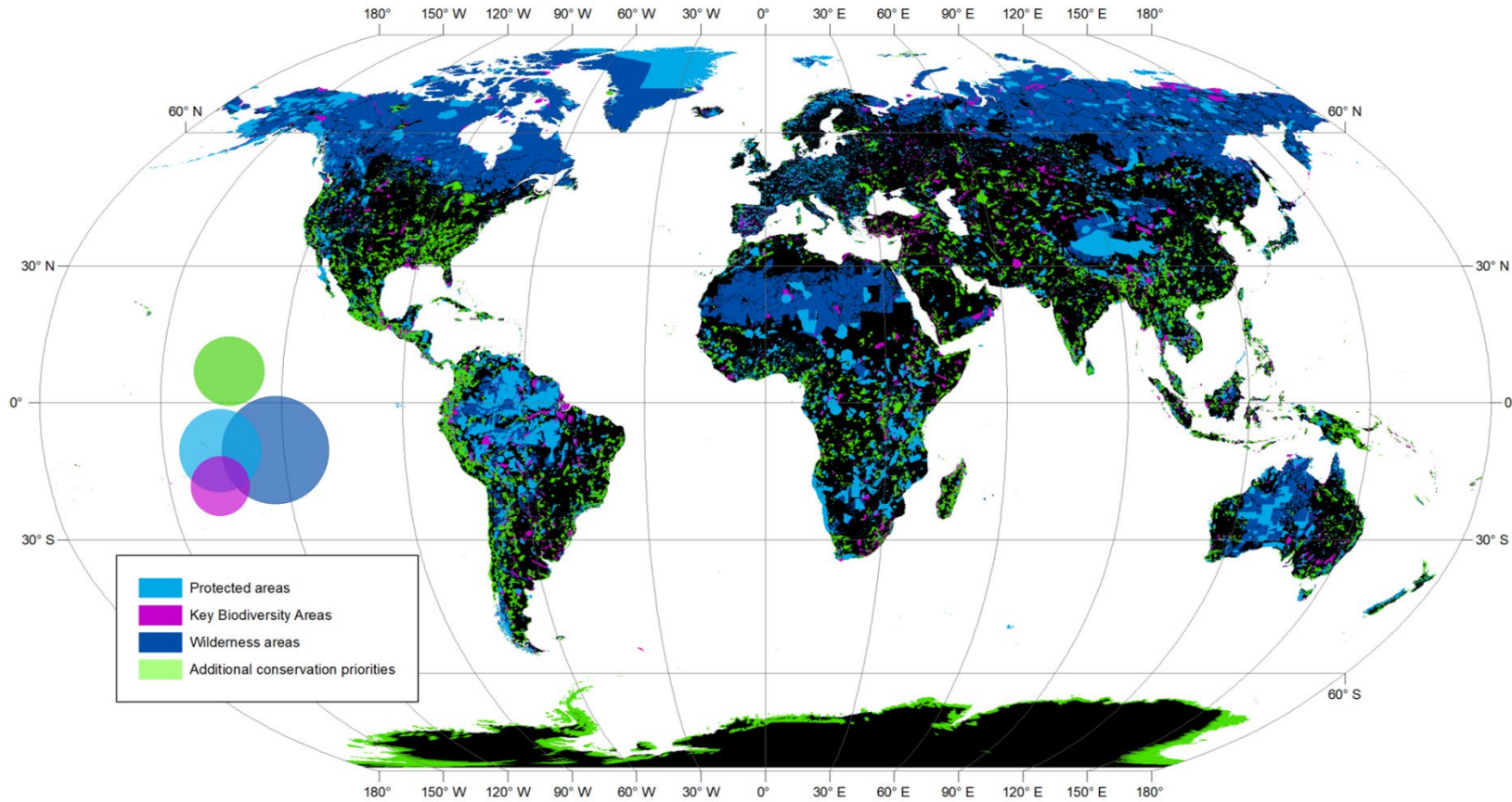
118 To highlight places that need immediate attention and potentially stronger forms
119 of environmental governance, we further calculate which parts of the land needing
120 conservation are most likely to suffer habitat conversion in the absence of
121 conservation. We do this by using recent harmonised projections of future land-use
122 change by 2030 and 2050³⁴. To determine best- and worst-case scenarios, we
123 evaluated projections under two different shared socioeconomic pathways (SSPs)³⁵
124 linked to representative concentration pathways (RCPs)³⁶: an optimistic scenario
125 where the world gradually moves towards a more sustainable future, SSP1 (RCP2.6;
126 IMAGE model), and a pessimistic scenario where regional rivalries dominate
127 international relations and land-use change is poorly regulated, SSP3 (RCP7.0; AIM
128 model). The areas we identify as at risk of habitat loss represent urgent priorities for
129 conservation action through site- and landscape-scale responses.

130 **The minimum land area requiring conservation**

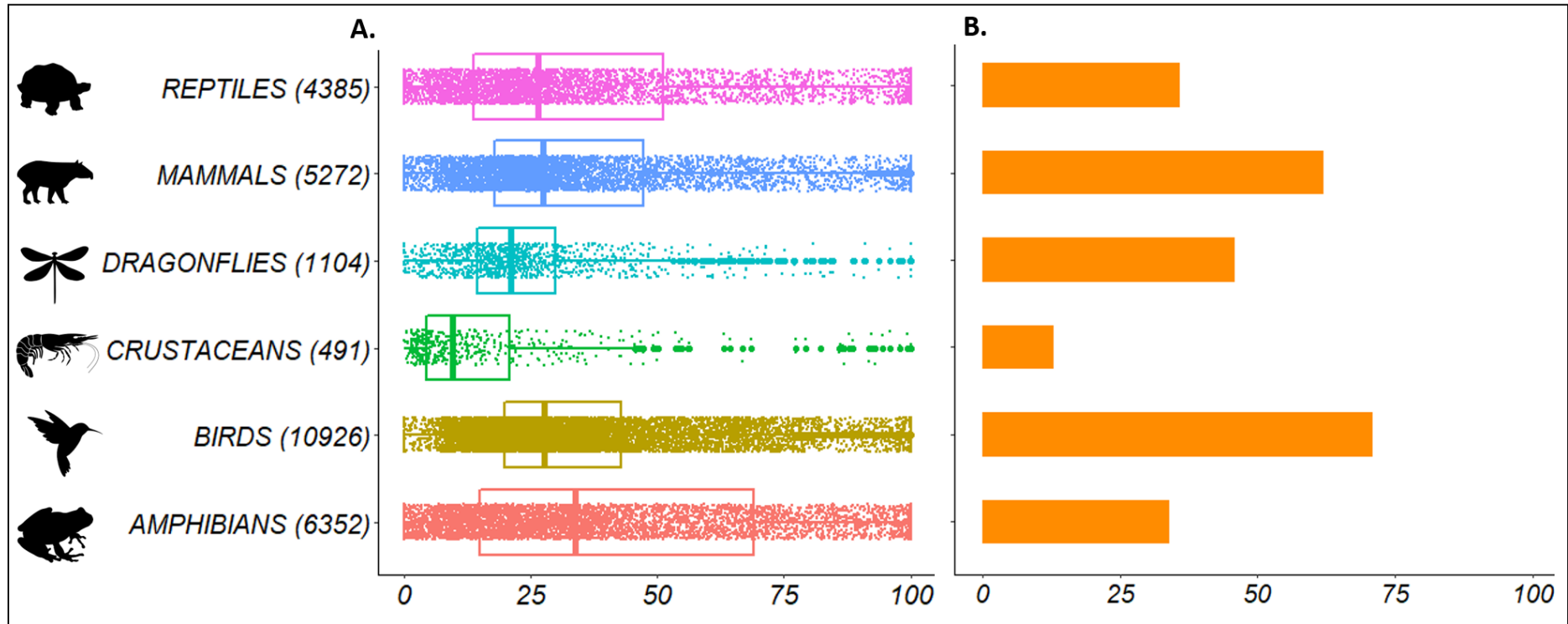
131 We estimate that, in total, the minimum land area that must be effectively conserved
132 covers 64 million km² (43.6% of Earth's terrestrial area; Figure 1). This consists of 35
133 million km² of wilderness, 21 million km² of existing PAs, 11 million km² of KBAs, and
134 13 million km² (9% of Earth's terrestrial area) of additional land needed to promote
135 species persistence based on conserving minimum proportions of their ranges (Figure
136 2). We find 1.9 million km² of overlap between PAs, KBAs and wilderness, amounting
137 to a relatively small 5% of wilderness extent, 9% of PA extent, and 18% of KBA extent.

138 There is considerable variation geographically in the amount of land requiring
139 effective conservation. We find that 60.6% of land in North America needs to be
140 conserved, primarily due to the wilderness areas of Canada and the USA and
141 extensive additional land areas in Central America. In contrast, only 32.3% of Europe's
142 land area requires conservation. The proportion of land requiring conservation also
143 varies considerably among nations (Figure 3), with notably high values in Canada
144 (79%), Costa Rica (83%), Suriname (84%), and Ecuador (81%), where these tropical-
145 country figures reflect high numbers of endemic species and, in Ecuador's case, a
146 large overlap with the remaining Amazon forest (Extended Data Table 1). We also find
147 that a larger proportion of land in developed countries (53%) requires effective
148 conservation compared to emerging economies (47%) or developing countries (34%)
149 (Extended Data Table 2). Many island nations have high proportions of land requiring

150 conservation (Figure 3; Supplementary Table 1), but this is likely an artefact of the
151 necessarily coarse resolution (30x30 km) of the analysis, where a few grid cells can
152 encompass an entire small island.



155 **Figure 1. The minimum land area for conserving terrestrial biodiversity.** The components include protected areas (light blue),
 156 Key Biodiversity Areas (purple) and wilderness areas (dark blue). Where they overlap, protected areas are shown above Key
 157 Biodiversity Areas, which are shown above wilderness areas. New conservation priorities are in green. The Venn diagram shows the
 158 proportional overlap between features.



160

161 **Figure 2. Gap analyses of species coverage within areas of conservation importance.** A) The percentage of each species'
 162 distribution overlapping with areas of conservation importance (protected areas, Key Biodiversity Areas, and wilderness areas).
 163 Boxplots show the median and 25th and 75th percentiles for each taxonomic group. B) the percentage of species with enough of
 164 their distribution overlapping existing conservation areas to meet their species-specific coverage target (orange).

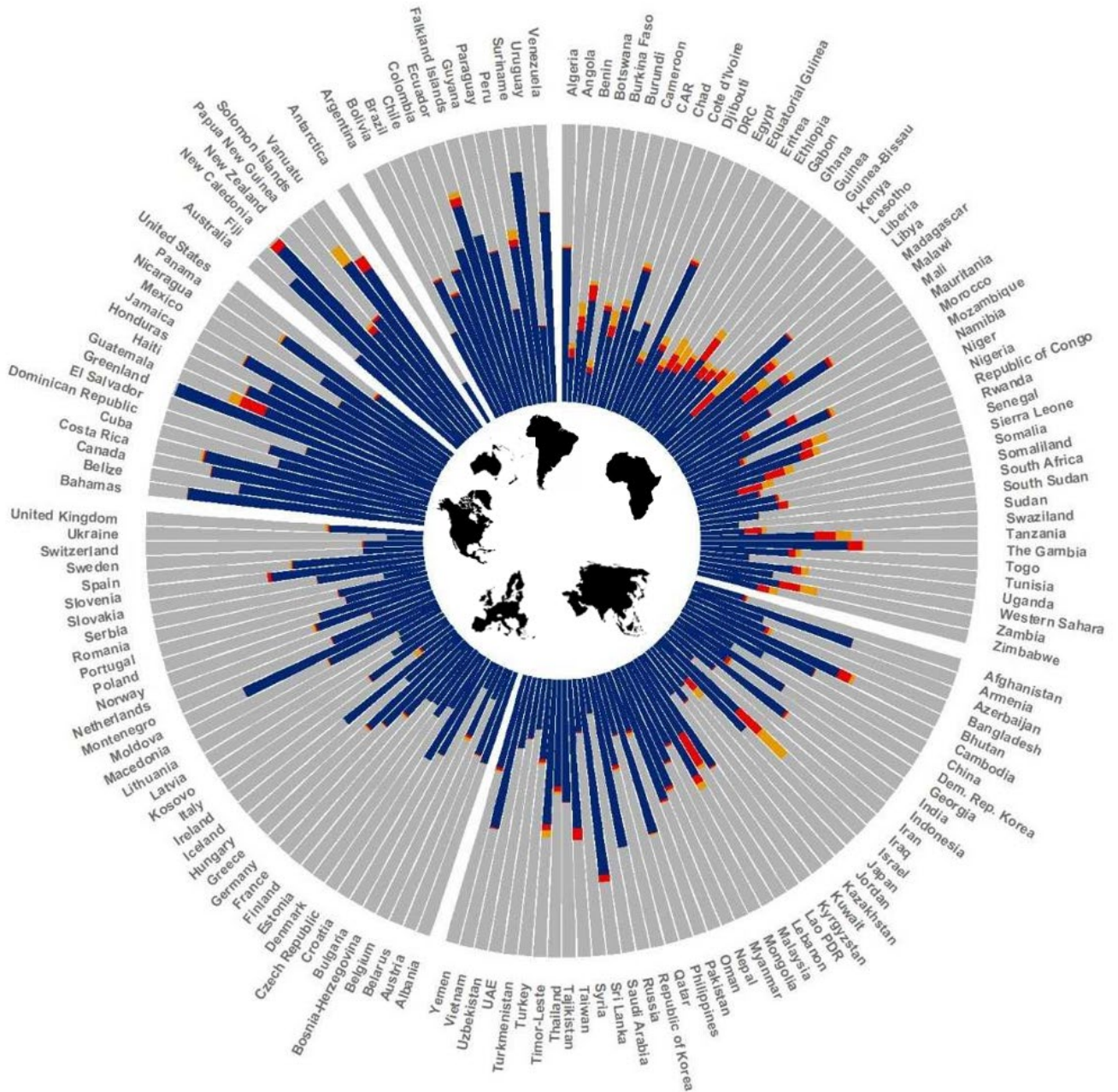
165 **Future risk of land conversion in areas requiring conservation**

166 Our results suggest that under the pessimistic scenario SSP3, 1.2 million km² (2%) of
167 the total land area requiring effective conservation will have its habitat converted to
168 human uses by 2030, increasing to 2.1 million km² (3.4%) by 2050 (Figure 4). Habitat
169 conversion varies across continents and countries; Africa is projected to have the
170 highest proportion of important conservation land converted by 2030 (>760,000 km²,
171 6.3%), increasing to 1.4 million km² (11.1%) by 2050 (Extended Data Table 3). The
172 lowest risk of conversion is in Oceania and North America. Substantially larger
173 proportions of land requiring conservation in developing countries are projected to
174 have their habitat converted by 2030 (4.3%), compared to emerging economies (1.3%)
175 or developed countries (0.8%).

176 Based on SSP1, representing a world acting on sustainability, we estimate that
177 130,000 km² (0.1%) of the land requiring effective conservation may suffer natural
178 habitat conversion by 2030, increasing to 3.8 million km² (0.5%) by 2050. This
179 highlights that our results are sensitive to future societal development pathways, but
180 even under the most optimistic scenario (SSP1), large extents of important
181 conservation land are at risk of having natural habitat converted to more intensive
182 human land-uses. We find very similar geographical patterns of risk under SSP1 as
183 those highlighted for SSP3.

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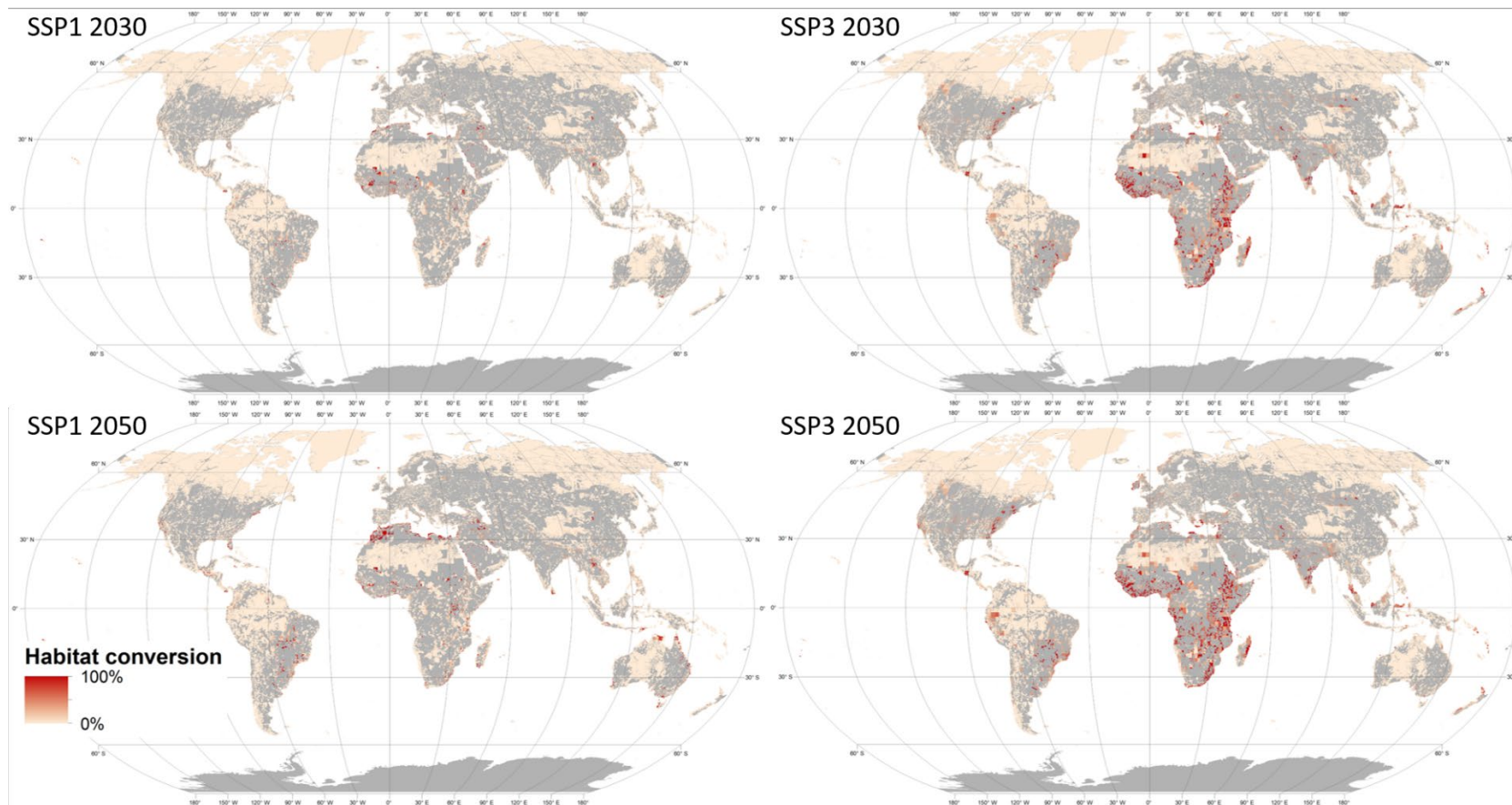
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187 **Figure 3. National level land area for conservation and projected habitat loss.**

188 Estimated proportion of each country requiring effective conservation attention that is
189 projected to suffer habitat conversion by 2030 (red), 2050 (orange) or that are
190 projected not to be converted (blue). Grey areas are outside the land identified for
191 conservation. Countries with a land area < 10,000 km² were excluded from the
192 figure.



193

194 **Figure 4. Future habitat conversion on important conservation land.** The location of land requiring effective conservation
 195 attention and the proportion of natural habitat projected to be converted to human uses by 2030 and 2050 based on Shared
 196 Socioeconomic Pathway 1 (SSP1; an optimistic scenario) and Shared Socioeconomic Pathway 3 (SSP3; a pessimistic scenario).
 197 Grey areas are not identified as existing conservation areas or additional conservation priorities. The data on future land use does
 198 not extend to Antarctica.

199 **Implications for global policy**

200 Our analyses represent the most comprehensive estimate of the minimum land area
201 requiring effective conservation attention in order to safeguard species and
202 ecosystems while accounting for current protected areas and areas of recognised
203 biodiversity importance (KBAs and Earth's remaining intact ecosystems). Given our
204 inclusion of wilderness areas and also updated maps of KBAs, our estimate that 43.6%
205 of land requires effective conservation is, unsurprisingly, larger than those from
206 previous analyses that have focussed primarily on species and/or ecosystems, or used
207 earlier KBA datasets (e.g. 27.9% Butchart, et al. ¹⁶, 20.2% Venter, et al. ¹⁵, and 30%
208 Larsen, et al. ⁴). Effectively conserving the land areas we identify would make a
209 substantial contribution towards achieving a suite of targets under the Convention for
210 Biological Diversity, including halting the extinction and decline of species (the focus
211 of CBD Aichi Target 12), protecting areas of particular importance for biodiversity
212 (Aichi Target 11), representing all native ecosystem types (Aichi Target 11), halting
213 the loss of natural habitats (Aichi Target 5) and securing areas that maintain ecological
214 and evolutionary processes³.

215 Encouraging nations to adopt a more ambitious conservation agenda within the
216 post-2020 biodiversity framework, and to scale up the proportion of land that is
217 effectively conserved, will be challenging. However, much (70%) of the land we identify
218 for conservation attention is still relatively intact, and therefore does not require costly
219 conservation interventions (such as vegetation restoration activities) beyond retention
220 policies that ensure these places remain intact³⁷. But at least 1.2 million km² of land
221 needing conservation - an area larger than South Africa representing 0.9% of Earth's
222 terrestrial surface - is both important for achieving our outlined conservation objectives
223 and likely to have its habitat converted to human uses by 2030. A tactical target aimed
224 at immediately safeguarding these at-risk places would make a significant contribution
225 towards addressing the biodiversity crisis, but only if combined with parallel efforts
226 ensuring that habitat conversion is not displaced into other important conservation
227 areas^{38,39}.

228 A diverse array of actions is required to achieve the scale of conservation
229 necessary to deliver positive conservation outcomes. These actions include ensuring
230 that the protected area estate is significantly expanded and managed more effectively

231 to benefit biodiversity¹², formally recognising and expanding other effective area-
232 based conservation measures, and implementing broad-scale responses aimed at
233 limiting core threatening processes such as habitat conversion. Another strategy that
234 may effectively limit the expansion of human pressures is to recognise Indigenous
235 Peoples' rights to land, benefit sharing, and institutions, so they can effectively
236 conserve their own lands, as there is substantial global overlap between Indigenous
237 lands and the important conservation land we identified⁴⁰. On all identified
238 conservation land, regardless of its immediate risk, the expansion of roads and
239 developments such as agriculture, forestry, and mining, need to be very carefully
240 managed to avoid net damage to ecosystems⁴¹. As such, mechanisms that direct
241 developments away from important conservation areas are also crucial, including
242 strengthening investment and performance standards (e.g. for financial organisations
243 such as the World Bank and other development investors⁴²), and tightening existing
244 industry certification standards.

245 A critical implementation challenge is that the proportion of land different
246 countries would need to conserve is highly inequitable. In responding to this inequity,
247 the conservation community could learn from how nations are addressing climate
248 change. For example, under the United Nations Framework Convention on Climate
249 Change, nations responsible for high levels of emissions of greenhouse gases are
250 obliged to make larger emission reductions⁴³, following the concept of common but
251 differentiated responsibilities that is foundational to all global environmental agendas
252 including the CBD⁴⁴. Since the burden of conservation is disproportionately distributed,
253 cost-sharing and fiscal transfer mechanisms are likely necessary to ensure that all
254 national participation is equitable and fair, and the opportunity costs of foregone
255 developments are considered^{45,46}. This is particularly important since the majority of
256 land requiring conservation attention and at risk of immediate habitat conversion is
257 found in developing nations.

258 Our estimate of the land area requiring effective biodiversity conservation must
259 be considered the bare minimum needed, and will almost certainly expand as more
260 data on the distributions of underrepresented species such as plants, invertebrates,
261 and freshwater species becomes available for future analyses⁴⁷. New KBAs will also
262 continue to be identified for under-represented taxonomic groups, threatened or
263 geographically-restricted ecosystems, and highly intact and irreplaceable ecosystems.

264 Species and ecosystems are also shifting under climate change, and as a result, are
265 leading to changes in the location of land requiring effective conservation⁴⁸, which we
266 could not account for. We also note that post-2020 biodiversity targets are likely to
267 require higher levels of ecoregional representation than the 17% we used (see
268 Methods). Finally, more land beyond the areas we identify will need to be conserved
269 for non-biodiversity conservation purposes, such as nature-based solutions to climate
270 change⁸.

271 For the above reasons, our results do not imply that the land our analysis did
272 not identify, the other 56.4% of Earth's land surface, is unimportant for conservation
273 and global sustainable development goals. Much of this area will be important for
274 sustaining the provision of ecosystem services to people, from climate regulation to
275 provisioning of food, materials, drinking water, and crop pollination, in addition to
276 supporting other elements of biodiversity not captured in our priority areas⁸.
277 Furthermore, many human activities can impact the entire Earth system regardless of
278 where they occur (e.g. fossil fuel use, pesticide use, and pollution), so management
279 efforts focussed on limiting the ultimate drivers of biodiversity loss are essential⁴⁹.
280 Finally, we have not considered how constraining developments to locations outside
281 of the land area needing conservation impacts solutions for meeting human needs,
282 such as increasing energy and food demands. Leakage of more intense land use
283 impacts into non-conservation priority areas must be carefully managed³⁸. Although
284 social objectives that lead to the betterment of all humanity are clearly important, they
285 cannot be all achieved sustainably without limiting the degradation of the ecosystems
286 supporting all life¹. Integrated assessments of how we can achieve multiple social
287 objectives while effectively conserving biodiversity at a global scale are important
288 avenues for future research⁵⁰.

289 The world's nations are already discussing new post-2020 biodiversity
290 conservation targets within the CBD and wider Sustainable Development Goals
291 international agenda. These targets will define the global conservation agenda for at
292 least the next decade, so it is crucial that they are adequate to achieve biodiversity
293 outcomes¹². Our analyses show that a minimum of 43.6% of land requires effective
294 conservation attention, through both site- and landscape-scale approaches, which
295 should serve as an ecological foundation for negotiations. If signatory nations are
296 serious about safeguarding the biodiversity and ecosystem services that underpin all

297 life on earth^{1,50}, then they need to recognise that conservation action must be
298 immediately and substantially scaled-up, in extent, intensity, and effectiveness.

299 **Methods**

300 **Mapping important conservation areas**

301 We obtained spatial data on the location of 214,921 PAs from the January 2017
302 version of the World Database on Protected Areas (WDPA)⁵¹. This edition still contains
303 data on PAs in China, which have largely been removed from the publicly accessible
304 WDPA in more recent versions. We handled the WDPA data according to best-
305 practice guidelines that are available on the protected planet website
306 (<https://www.protectedplanet.net/c/calculating-protected-area-coverage>) and included
307 regionally, nationally and internationally designated PAs. The WDPA dataset contains
308 PAs represented as point data. In these cases, we converted the points to polygons
309 by setting a geodesic buffer around the point based on the areal attributes of that point.
310 We excluded points with no areal attributes. We also excluded all marine PAs,
311 'proposed' PAs, and UNESCO Man and Biosphere Reserves since their core
312 conservation areas often overlap with other PAs and their buffer zones' primary goals
313 are not biodiversity conservation. Finally, we flattened (i.e. dissolved) the PA data to
314 remove any overlapping PAs.

315 We obtained data on the boundaries of 14,192 KBAs from the January 2017
316 version of the World Database of Key Biodiversity Areas⁵². KBAs documented with
317 point data were treated as outlined above for PAs. We obtained global data on
318 wilderness extent from Allan, et al. ⁵³, utilising maps of 'pressure-free lands'. We
319 merged PAs, KBAs and wilderness areas together, removing overlaps (i.e. again
320 flattened the merged datasets) to create a global template of "existing important
321 conservation areas".

322 **Distribution and representation of biodiversity**

323 We obtained data on the distributions of terrestrial mammals (n=5,272), amphibians
324 (n=6,352), reptiles (including marine turtles; n=4,385), freshwater crayfish (n=491) and
325 dragonflies and damselflies (order Odonata; n=1,104) from the IUCN Red List of
326 Threatened Species⁵⁴. Bird distribution data (n=10,926) were sourced from BirdLife
327 International and Handbook of the Birds of the World⁵⁵. These represent the most
328 comprehensive spatial databases for these taxonomic groups, although crayfish,
329 Odonata, and reptiles are likely still undersampled. We also included data on the

330 distribution of terrestrial ecoregions³⁰, which are bio-geographically distinct spatial
331 units at the global scale.

332 We set representation targets for the percentage of each species' distribution
333 that should be effectively conserved, following previous studies (Rodrigues, et al. ²⁹,
334 Venter, et al. ¹⁵, and Butchart, et al. ¹⁶). Targets were set as a function of a species'
335 range size, and were log-linearly scaled between 10% for species with distributions
336 >250,000km², to 100% for species with ranges <1,000km². We limited the target for
337 species with large ranges to 1 million km² maximum¹⁶. For each ecoregion we
338 followed¹⁵ by setting a coverage target of 17%, in line with Aichi Target 11 of the
339 Strategic Plan for Biodiversity³. We acknowledge that Aichi Target 11 expires in 2020,
340 and that other target setting approaches are being developed, such as those based
341 on species persistence⁵⁶, but these are currently unpublished (and the nature of post-
342 2020 targets is still under discussion) so we chose to proceed with the widely accepted
343 method developed by Rodrigues, et al. ²⁹. We carried out a "gap analysis" by
344 calculating the proportion of each species' range that currently overlaps with the
345 important conservation areas, and comparing this with each species' coverage target
346 to identify under-represented species and the extent of additional range each requires.

347 **Priority areas for the expansion of conservation efforts**

348 We used integer linear programming to identify spatial priorities for meeting species
349 conservation targets, whilst accounting for current protection within existing important
350 conservation areas, and minimizing the cost (human footprint⁵⁷) of the areas selected
351 (the minimum set problem)⁵⁸. We used Gurobi software (version 5.6.2) to run the
352 spatial prioritisation, following methods developed by Beyer, et al. ⁵⁹ that account for
353 multi-species complementarity. Integer linear programming can reach optimal
354 solutions to conservation problems if unrestricted by computing time. We applied a
355 threshold specifying that solutions must be within 0.5% of the optimum⁵⁹, which returns
356 a near-optimal solution and greatly reduces processing time.

357 To run the analysis, we first created a 30 x 30 km (900 km²) global planning
358 unit grid. This resolution limits the risk of commission errors when working with the
359 available species distribution data (e.g. assuming a species is present when it is
360 not)^{16,60}. Planning units were clipped to terrestrial areas and inland lakes and
361 waterways so that freshwater taxa could be included. We included Antarctica and

362 Greenland. We calculated the area of each conservation feature (e.g. species
363 distribution and ecoregion distribution) within each planning unit, including the area
364 within existing important conservation areas. All geospatial data processing was
365 carried out in the Mollweide equal-area projection using a spatially enabled
366 PostgreSQL database (using PostGIS version 2.2) or in ESRI ArcGIS version 10.5.1.

367 We used the sum of the human footprint⁵⁷ as a surrogate for the cost of
368 conservation in each planning unit. The human footprint is a map of cumulative human
369 pressure on the natural environment for the year 2009 at a 1km² resolution globally.
370 We assumed that conservation will be cheaper and more feasible in areas with less
371 human influence, and that places classified as 'built areas' are unavailable for
372 conservation. By built areas we mean cities and major urban centres that contain no
373 original habitat. Planning units beyond the extent of the human footprint (e.g. ice-free
374 regions of Antarctica and remote sub-Antarctic islands) were set a cost of zero.

375 We repeated the entire prioritisation analysis with two additional planning unit
376 grids. These grids were still 30 x 30 km in scale but the cells were shifted 10km East
377 and North of the original grid, and 10km South and West of the original grid. This limits
378 uncertainty associated with the placement of the grid, and to the best of our
379 knowledge, our analysis is the first to use such an approach. Areal statistics reported
380 in the methods are based on the original grid, whilst on the maps all three grids are
381 presented simultaneously with a degree of transparency so that priority areas selected
382 in all three analyses are highlighted. This approach also ensures a degree of fuzziness
383 in the priority area boundaries in the maps, demonstrating to decision makers that,
384 while scale and location of planning units will introduce subtle differences in any
385 prioritization scenario, certain areas always stand-out as conservation priorities.

386 **Future threats to conservation areas**

387 To map the risk of habitat conversion occurring in the conservation areas identified,
388 we utilised spatially explicit data on future land-use scenarios from the newly released
389 Land Use Harmonisation Dataset v2 (<http://luh.umd.edu/>)³⁴. To determine best- and
390 worst-case scenarios, we evaluated projections under two different Shared
391 Socioeconomic Pathways (SSPs)³⁵, which are linked to Representative Concentration
392 Pathways (RCPs)³⁶: specifically, SSP1 (RCP2.6; IMAGE), an optimistic scenario

393 where the world gradually moves towards a more sustainable future, and SSP3
394 (RCP7.0; AIM), a pessimistic scenario where land use change is poorly regulated.

395 The harmonised land-use data contains 12 state layers (with the unit being the
396 fraction of a grid cell in that state) for the years 2015 (current baseline), 2030 and
397 2050. We considered four of the state layers as natural land-cover classes, including;
398 primary forested land, primary non-forested land, potentially forested secondary land,
399 and potentially non-forested secondary land. Using these four classes, we calculated
400 the proportion of natural land projected to be lost (converted to human uses) by the
401 years 2030 and 2050 in each 30 x 30 km grid cell. From this we calculated the area of
402 natural land projected to be lost within each grid cell. We assume that once land is
403 converted it remains converted. Antarctica and remote islands were excluded from this
404 part of the analyses because the land-use data does not extend to them.

405

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549 **Acknowledgements**

550 We thank Peadar Brehony for thoughtful comments on the manuscript.

551

552 **Author Contributions**

553 J.R.A and J.E.M.W. framed the study. J.R.A., S.C.A., M.D.M. carried out the
554 analyses. All authors discussed and interpreted the results. J.R.A and J.E.M.W.
555 wrote the manuscript with support from all authors.

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557 **Competing interests**

558 The authors declare no competing interests