Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment

Article (Accepted Version)

Published in *Science* DOI: 10.1126/science.aaf2201

Title: Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment

Authors: Tim Newbold[1,2,*], Lawrence N. Hudson[3], Andrew P. Arnell[1], Sara Contu[3], Adriana De Palma[3,4], Simon Ferrier[5], Samantha L. L. Hill[1,3], Andrew J. Hoskins[5], Igor Lysenko[4], Helen R. P. Phillips[3,4], Victoria J. Burton[3], Charlotte W.T. Chng[3], Susan Emerson[3], Di Gao[3], Gwilym Pask-Hale[3], Jon Hutton[1,6], Martin Jung[7,8], Katia Sanchez-Ortiz[3], Benno I. Simmons[3,4], Sarah Whitmee[2], Hanbin Zhang[3], Jörn P.W. Scharlemann[8,1], Andy Purvis[3,4]

Affiliations:

[1]United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge CB3 0DL, UK.

[2]Centre for Biodiversity and Environment Research, Department of Genetics, Evolution and Environment, University College London, Gower Street, London WC1E 6BT, UK.

[3]Department of Life Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, UK.

[4]Department of Life Sciences, Imperial College London, Silwood Park, London SL5 7PY, UK.

[5]CSIRO Land and Water Flagship, Canberra, Australian Capital Territory 2601, Australia.

[6]Luc Hoffmann Institute, WWF International, 1196 Gland, Switzerland.

[7]Center for Macroecology, Evolution and Climate, Natural History Museum of Denmark, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen Ø, Denmark.

[8]School of Life Sciences, University of Sussex, Brighton BN1 9QG, UK.

*Corresponding author. E-mail: t.newbold@ucl.ac.uk.

One Sentence Summary: Land use has reduced biosphere intactness below safe limits across most of the terrestrial surface, especially in grassland biomes.

Abstract: Land use and related pressures have reduced local terrestrial biodiversity, but it is unclear how the magnitude of change relates to the recently proposed planetary boundary ('safe limit'). We estimate that land use and related pressures have already reduced local biodiversity intactness – the average proportion of natural biodiversity remaining in local ecosystems – beyond its recently-proposed planetary boundary across 58.1% of the world's land surface, where 71.4% of the human population live. Biodiversity intactness within most biomes (especially grassland biomes), most biodiversity hotspots, and even some wilderness areas, is inferred to be beyond the boundary. Such widespread transgression of safe limits suggests that biodiversity loss, if unchecked, will undermine efforts towards long-term sustainable development.

Main Text:

Land use and related pressures have been the main drivers of terrestrial biodiversity change (*1*) and are increasing (*2*). Biodiversity has already experienced widespread large net losses (*3*), potentially compromising its contribution to resilient provision of ecosystem functions and services, such as biomass production and pollination, that underpin human wellbeing (*4–7*). Species-removal experiments suggest that loss of ecosystem function accelerates with ongoing species loss (*5*), implying there may be thresholds beyond which human intervention is needed to ensure adequate local ecosystem function (*8*, *9*). The loss of 20% of species – which affects ecosystem productivity as strongly as other direct drivers (*5*) – is one possible threshold, but it is unclear by which mechanism species richness affects ecosystem function, and whether there are direct effects or only effects on resilience of function (*6*, *7*). Whereas this proposed safe limit comes from studies of local ecosystem health, the Planetary Boundaries framework (*8*, *9*) considers longer-term maintenance of function over much larger (biome to global) scales. At these temporal and spatial scales, the maintenance of function depends on functional diversity – the ranges and abundances of the functional traits of the species present (*8*, *10*). As direct functional trait data are lacking, the Biodiversity Intactness Index (BII: the average abundance of originally present species across a broad range of species, relative to abundance in undisturbed habitat; (*11*)) is suggested as the best metric (*8*, *9*). The safe limit is placed at a precautionary 10% reduction in BII, but it might be as high as a 70% reduction (*9*).

A key uncertainty when estimating safe limits concerns the value of species not present in the undisturbed ecosystem. Such species could benefit ecosystem functioning, have no effect (as assumed by the BII), or even impair it (*12–15*). Most models estimating net human impacts on biodiversity (*3*, *16*) treat novel and originally-present species as functionally equivalent, whereas experimental studies manipulate species originally present (*17*).

Given the possibly severe consequences of transgressing safe biodiversity limits, global assessments of relevant metrics are needed urgently. Data limitations have hampered efforts to date: BII has so far only been estimated, from expert opinion, for seven southern African countries (*11*). More recently, we combined global models linking land-use pressures to local biodiversity with global land-use maps. We estimated that net reductions in local species richness exceeded 20% across 28% of the world's land surface by 2005, while 48.7% of land had seen net reductions in total abundance of ≥ 10% (*3*). However, our projections of net effects did not account for any reductions of originally-present diversity that were offset by influx of novel species (*18*), as well as being at too coarse a scale (~50 km^2) to be relevant for local ecosystem functioning and decision making. Furthermore, we did not analyze the spatial distribution of the transgression of proposed safe limits.

Here we present fine-scale (~1km^2) global estimates of how land-use pressures have affected the numbers of species and individuals found in samples from local terrestrial ecological assemblages (*19*). To explore different assumptions about novel species, we estimate both overall net change (correct if novel species contribute fully to ecosystems) and – using estimates of species turnover among land uses to exclude novel species – change in species originally present (correct if novel species play no role). We ask how much of the Earth's land surface is already 'biotically compromised' (i.e. exceeds the boundaries of 10% loss of abundance or 20% loss of species). We focus on results for the relative abundance of originally-present species (BII), because this is the measure suggested in the Planetary Boundaries framework (*9*). We estimate average losses per biome, because of the suggested importance of biomes for the functioning of the whole Earth System (*8*, *9*), and to assess possible consequences for people – assuming that many biodiversity-regulated ecosystem services operate locally – we quantify the geographical congruence between biodiversity reduction and human population. We also assess the biotic integrity of areas identified as particularly important for conservation (although the proposed planetary boundary in terms of BII may not always be relevant for areas much smaller than biomes, and probably needs to vary depending on the sensitivity of the biota). First, Conservation International's 'Biodiversity Hotspots' – areas rich in endemic species but with high levels of habitat loss – have been suggested as urgent conservation priorities (*20*). Because these areas were identified reactively (*20*) with a criterion of 70% loss of primary vegetation, we expect them to have lower biodiversity intactness than average. For comparison, we also estimate the biodiversity intactness of Conservation International's High Biodiversity Wilderness Areas, which also meet the criterion of high species endemism, but which retain 70% of their natural habitat and so present more opportunity for proactive conservation (*20*).

We modelled how sampled richness and abundance respond to land-use pressures using data from the PREDICTS (Projecting Responses of Ecological Diversity in Changing Terrestrial Systems) database (*21*). These data consisted of 2,382,624 records (Fig. S1; nearly twice as many as our earlier, coarser-scale analyses (*3*)) of the abundance (1,888,784 records) or else occurrence of 39,123 species at 18,659 sites. The hierarchical mixed-effects models we used considered four pressure variables – land use, land-use intensity, human population density and proximity to the nearest road – as fixed effects (Figs. S2-3), while random effects accounted for among-study differences in sampling (methods, effort and focal taxonomic groups) and for the spatial arrangement of sampled sites within studies (see Supplementary Methods). We had insufficient data to fit separate models for each biome or clade. Responses may vary taxonomically or geographically, although our earlier analyses (*3*) showed no significant differences among plants, invertebrates and vertebrates, and suggested limited variation among biomes. As more data become available, future analyses will be better able to reflect any differences in response. We combined the models of species richness and total abundance with models of species turnover among land uses (based on *24*, but adapted to reflect asymmetric differences among land uses), to discount the fraction of species absent in non-primary habitat (see Methods for details). To map modelled responses, we used global pressure data for the year 2005 at a resolution of 30 arc seconds (approximately 1 km^2). We used land-use estimates for 2005 (*25*), and estimated land-use intensity as in (*3*); human population (for the year 2000) came from (*22*) and proximity to nearest road from (*23*). Values of the response variables are always expressed relative to an intact assemblage undisturbed by humans, so do not rely on estimates of absolute abundance or species richness, which vary widely among biomes and taxa.

Our map of terrestrial BII (Fig. 1A; Fig. S4) suggests that the average local abundance of originally present species (*11*) globally has fallen to 84.6% (95% confidence interval: 82.2-91.6%) of its value in the absence of human land-use effects, probably below the value (90%) proposed as a safe limit (*9*). Considering net changes in abundance, as in (3), assuming that novel species contribute fully to ecosystem function, global average abundance has fallen to 88.0% (95% CI: 83.5-94.8%) of its value before human effects.

Assuming that only originally present species contribute to ecosystem function, most of the world's land surface is biotically compromised in terms of BII (58.1% of terrestrial area; 95% CI: 40.4-70.2%; Fig. 1A) and within-sample richness of originally present species (62.4%; 95% CI: 20.0-72.7%; Fig. 1B). If the proposed boundaries are broadly correct, ongoing human intervention may be needed to ensure delivery of ecosystem functions across most of the world (*5*). The proposed planetary boundary for BII (*9*) had uncertainty ranging from 30% to 90%; the proportion of the land surface exceeding the boundary varies widely across this range (Fig. S5), highlighting the urgent need for better understanding of how BII relates to Earth-system functioning (*9*). Assuming that novel species contribute as much to ecosystems as originally present species we estimate the safe limit for total abundance to have been crossed in 48.4% (95% CI: 30.9-66.5%) of land (Fig. 1C) and that for within-sample species richness in 58.4% (95% CI: 21.8-75.0%; Fig. 1D). Even assuming that novel species have no effect on ecosystem function will be optimistic if they actually impair it, an important question to test in future. Most people (71.4%) live in biotically compromised areas, as judged by BII (Fig. 2), although uncertainty in this result was high (95% CI: 8.7-92.4%). There is growing evidence that access to high-biodiversity areas benefits people's physical and psychological wellbeing (*26*, *27*), although uncertainty remains over which aspects of biodiversity are important.

The biodiversity impact of land-use pressures varies among biomes (Fig. 3A; Table S2): grasslands are most affected, and tundra and boreal forests least. Our BII estimates suggest 9 of the 14 terrestrial biomes (95% CI: 4-12) have on average transgressed safe limits for biodiversity (Fig. 3A), although this number drops to seven (95% CI: 1-12) if novel species are included. The BII limit has been crossed in 22 of 34 terrestrial 'Biodiversity Hotspots' (*28*) (95% CI: 7-31; Fig. 3B; Table S3); this figure falls to 12 (95% CI: 5-32) if novel species are included, again highlighting the need to understand their effects on ecosystem function. Given that Biodiversity Hotspots were identified partly based on widespread historical habitat loss (*20*), their low average BII is unsurprising, although our results suggest that at least some hotspots might stay within safe ecological limits if future land conversion is reduced. In contrast, three out of the five High Biodiversity Wilderness Areas, which were identified for conservation proactively because the habitat is still relatively intact (*20*), have not experienced average losses of local biodiversity (BII) that cross the planetary boundaries (95% CI: 2-4; Fig. 3C; Table S4; four out of five if novel species are included; 95% CI: 2-5). Results concerning which areas have crossed proposed planetary boundaries were generally consistent between the richness- and abundance-based biodiversity measures (Figure 3; Tables S2-4).

Our models suggest generally smaller impacts of land use on BII than a previous study (*11*). This might reflect differences in taxonomic coverage, but there are also two reasons why our results may overestimate BII. First, we ignore lagged responses. Second, our models use sites in primary vegetation as a baseline, because historical data are so rare (*3*, *11*); these sites will often have experienced some human impact. Nevertheless, it is important to note that since our models are global, their baseline is not biome- or region-specific, and they do not rely on data from minimally impacted land use from heavily modified landscapes, where such conditions do not exist. Our data have good coverage of taxa and biomes (Fig. S1), but the density of sampling is inevitably uneven. Biomes that are particularly underrepresented, relative to their global ecosystem productivity, are boreal forests, tundra, flooded grasslands and savannas and mangroves (Fig. S1), meaning that less confidence can be placed in the results for these biomes. The data probably also under-represent soil and canopy species. The estimate of land area biotically compromised in terms of species richness is much higher than our previous assessment (58.4 vs. 28.4%, although the confidence intervals overlap), but the estimates based on total abundance are almost identical (48.4% vs. 48.7%; *3*). The discrepancy for species richness is because of a stronger modelled interaction here between land use and human population density (Fig. S3), and because we include the effect of roads and the interaction between roads and land use, which were omitted from the projections in (*3*).

The Sustainable Development Goals adopted in September 2015 (*29*) aim to improve human wellbeing while protecting, restoring and sustainably using terrestrial ecosystems. Our results highlight the magnitude of the challenge. Exploitation of terrestrial systems has been vital for human development throughout history (*30*), but the cost to biosphere integrity has been high. Slowing or reversing the global loss of local biodiversity will require preserving the remaining areas of natural (primary) vegetation and, so far as possible, restoring human-used lands to natural (secondary) vegetation. Such an outcome would be beneficial for biodiversity, ecosystems and – at least in the long term – human wellbeing.

References and Notes:

1. J.-C. Vié, C. Hilton-Taylor, S. N. Stuart, *Wildlife in a changing world: an analysis of the 2008 Red List of Threatened Species* (IUCN, Gland, Switzerland, 2009).
2. D. P. Tittensor et al., *Science* **346**, 241–244 (2014).
3. T. Newbold et al., *Nature* **520**, 45–50 (2015).
4. B. J. Cardinale et al., *Nature* **486**, 59–67 (2012).
5. D. U. Hooper et al., *Nature*. **486**, 105–108 (2012).
6. Y. Hautier et al., *Science* **348**, 336–340 (2015).
7. T. H. Oliver et al., *Trends Ecol. Evol.* **30**, 673–684 (2015).
8. G. M. Mace et al., *Glob. Environ. Chang.* **28**, 289–297 (2014).
9. W. Steffen et al., *Science* **347**, 1259855 (2015).
10. S. Díaz, M. Cabido, *Trends Ecol. Evol.* **16**, 646–655 (2001).
11. R. J. Scholes, R. Biggs, *Nature* **434**, 45–49 (2005).
12. P. M. Vitousek, *Oikos* **57**, 7–13 (1990).
13. J. M. Levine et al., *Proc. R. Soc. London B* **270**, 775–781 (2003).
14. L. Pejchar, H. A. Mooney, *Trends Ecol. Evol.* **24**, 497–504 (2009).
15. M. Vilà et al., *Ecol. Lett.* **14**, 702–708 (2011).
16. L. Gibson et al., *Nature* **478**, 378–381 (2011).
17. M. Vellend et al., *Proc. Natl. Acad. Sci. U. S. A.* **110**, 19456–9 (2013).
18. C. D. Thomas, *Proc. Natl. Acad. Sci. U. S. A.* **110**, 19187–8 (2013).
19. Materials and methods are available as supplementary materials on Science Online.
20. T. M. Brooks et al., *Science* **313**, 58–61 (2006).
21. L. N. Hudson et al., *Ecol. Evol.* **4**, 4701–4735 (2014).
22. CIESIN, IFPRI, CIAT, *Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Population Density Grid.* (NASA SEDAC, Palisades, NY, United States, 2011; http://sedac.ciesin.columbia.edu/data/dataset/grump-v1-population-density).
23. CIESIN, ITOS, University of Georgia, *Global Roads Open Access Data Set, Version 1 (gROADSv1)* (NASA SEDAC, Palisades, NY, United States, 2013; http://dx.doi.org/10.7927/H4VD6WCT).
24. T. Newbold et al., *Ecography* (in press). doi: 10.1111/ecog.01932

25. A. J. Hoskins et al., *Ecol. Evol.* (in press). doi: 10.1002/ece3.2104

26. R. A. Fuller, K. N. Irvine, P. Devine-Wright, P. H. Warren, K. J. Gaston, *Biol. Lett.* **3**, 390–394 (2007).

27. P. A. Sandifer, A. E. Sutton-Grier, B. P. Ward, *Ecosyst. Serv.* **12**, 1–15 (2015).

28. N. Myers, R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, J. Kent, *Nature* **403**, 853–858 (2000).

29. United Nations, *UN General Assembly Resolution A/RES/70/1* (2015, http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E).

30. E. C. Ellis et al., *Proc. Natl. Acad. Sci. U. S. A.* **110**, 7978–85 (2013).

31. J. Aben, M. Dorenbosch, S. K. Herzog, A. J. P. Smolders, G. Van Der Velde, Human disturbance affects a deciduous forest bird community in the Andean foothills of central Bolivia. *Bird Conserv. Int.* **18**, 363–380 (2008).

32. G. B. Adum, M. P. Eichhorn, W. Oduro, C. Ofori-Boateng, M. O. Rodel, Two-stage recovery of amphibian assemblages following selective logging of tropical forests. *Conserv. Biol.* **27**, 354–363 (2013).

33. V. Aguilar-Barquero, F. Jiménez-Hernández, Diversidad y distribución de palmas (Arecaceae) en tres fragmentos de bosque muy húmedo en Costa Rica. *Rev. Biol. Trop.* **57**, 83–92 (2009).

34. E. L. Alcala, a. C. Alcala, C. N. Dolino, Amphibians and reptiles in tropical rainforest fragments on Negros Island, the Philippines. *Environ. Conserv.* **31**, 254–261 (2004).

35. O. E. Alcayaga, J. Pizarro-Araya, F. M. Alfaro, J. Cepeda-Pizarro, Spiders (Arachnida, Araneae) associated to agroecosystems in the Elqui Valley (Coquimbo Region, Chile). *Rev. Colomb. Entomol.* **39**, 150–154 (2013).

36. M. del M. Alguacil, E. Torrecillas, G. Hernandez, A. Roldan, Changes in the diversity of soil arbuscular mycorrhizal fungi after cultivation for biofuel production in a Guantanamo (Cuba) tropical system. *PLoS One*. **7** (2012), doi:10.1371/journal.pone.0034887.

37. A. Alignier, M. Deconchat, Patterns of forest vegetation responses to edge effect as revealed by a continuous approach. *Ann. For. Sci.* **70**, 601–609 (2013).

38. A. N. Andersen, B. D. Hoffmann, Conservation value of low fire frequency in tropical savannas: ants in monsoonal northern Australia. *Austral Ecol.* **36**, 497–503 (2011).

39. E. Arbeláez-Cortés, H. A. Rodríguez-Correa, M. Restrepo-Chica, Mixed bird flocks: patterns of activity and species composition in a region of the Central Andes of Colombia. *Rev. Mex. Biodivers.* **82**, 639–651 (2011).

40. I. Armbrecht, I. Perfecto, E. Silverman, Limitation of nesting resources for ants in Colombian forests and coffee plantations. *Ecol. Entomol.* **31**, 403–410 (2006).

41. J. Arroyo, J. C. Iturrondobeitia, C. Rad, S. Gonzalez-Carcedo, Oribatid mite (Acari) community structure in steppic habitats of Burgos Province, central northern Spain. *J. Nat. Hist.* **39**, 3453–3470 (2005).

42. B. Azhar *et al.*, The influence of agricultural system, stand structural complexity and landscape context on foraging birds in oil palm landscapes. *Ibis* **155** (2013), pp. 297–312.

43. N. M. Azman *et al.*, Avian diversity and feeding guilds in a secondary forest, an oil palm plantation and a paddy field in Riparian areas of the Kerian River Basin, Perak, Malaysia. *Trop. Life Sci. Res.* **22**, 45–64 (2011).

44. A. B. Azpiroz, J. G. Blake, Avian assemblages in altered and natural grasslands in the northern Campos of Uruguay. *Condor* **111**, 21–35 (2009).
45. L. Baeten *et al.*, Early trajectories of spontaneous vegetation recovery after intensive agricultural land use. *Restor. Ecol.* **18**, 379–386 (2010).
46. L. Baeten, M. Hermy, S. Van Daele, K. Verheyen, Unexpected understorey community development after 30 years in ancient and post-agricultural forests. *J. Ecol.* **98**, 1447–1453 (2010).
47. A. Báldi, P. Batáry, S. Erdős, Effects of grazing intensity on bird assemblages and populations of Hungarian grasslands. *Agric. Ecosyst. Environ.* **108**, 251–263 (2005).
48. J. E. Banks, P. Sandvik, L. Keesecker, Beetle (Coleoptera) and spider (Araneae) diversity in a mosaic of farmland, edge, and tropical forest habitats in western Costa Rica. *Pan-Pac. Entomol.* **83**, 152–160 (2007).
49. S. K. Baral, K. Katzensteiner, Diversity of vascular plant communities along a disturbance gradient in a central mid-hill community forest of Nepal. *Banko Janakari*. **19**, 3–7.
50. J. Barlow *et al.*, Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. *Proc. Natl. Acad. Sci. U. S. A.* **104**, 18555–18560 (2007).
51. J. Barlow, L. A. M. Mestre, T. A. Gardner, C. A. Peres, The value of primary, secondary and plantation forests for Amazonian birds. *Biol. Conserv.* **136**, 212–231 (2007).
52. J. Barlow, W. L. Overal, I. S. Araujo, T. A. Gardner, C. A. Peres, The value of primary, secondary and plantation forests for fruit-feeding butterflies in the Brazilian Amazon. *J. Appl. Ecol.* **44**, 1001–1012 (2007).
53. B. I. P. Barratt *et al.*, Biodiversity of indigenous tussock grassland sites in Otago, Canterbury and the central North Island of New Zealand I. The macro-invertebrate fauna. *J. R. Soc. New Zeal.* **35**, 287–301 (2005).
54. B. I. P. Barratt *et al.*, Biodiversity of indigenous tussock grassland sites in Otago, Canterbury and the Central North Island of New Zealand VI. Coleoptera biodiversity, community structure, exotic species invasion, and the effect of disturbance by agricultural development. *J. R. Soc. New Zeal.* **42**, 217–239 (2012).
55. L. Barrico *et al.*, Biodiversity in urban ecosystems: Plants and macromycetes as indicators for conservation planning in the city of Coimbra (Portugal). *Landsc. Urban Plan.* **106**, 88–102 (2012).
56. P. Bartolommei, A. Mortelliti, F. Pezzo, L. Puglisi, Distribution of nocturnal birds (Strigiformes and Caprimulgidae) in relation to land-use types, extent and configuration in agricultural landscapes of Central Italy. *Rend. Lincei-Scienze Fis. E Nat.* **24**, 13–21 (2013).
57. Y. Basset *et al.*, Changes in arthropod assemblages along a wide gradient of disturbance in Gabon. *Conserv. Biol.* **22**, 1552–63 (2008).
58. A. J. Bates *et al.*, Changing bee and hoverfly pollinator assemblages along an urban-rural gradient. *PLoS One*. **6** (2011), doi:10.1371/journal.pone.0023459.
59. B. Baur *et al.*, Effects of abandonment of subalpine hay meadows on plant and invertebrate diversity in Transylvania, Romania. *Biol. Conserv.* **132**, 261–273 (2006).
60. S. Benedick *et al.*, Impacts of rain forest fragmentation on butterflies in northern Borneo: species richness, turnover and the value of small fragments. *J. Appl. Ecol.* **43**, 967–977 (2006).
61. A. Berg, K. Ahrne, E. Ockinger, R. Svensson, B. Soderstrom, Butterfly distribution and abundance is affected by variation in the Swedish forest-farmland landscape. *Biol. Conserv.* **144**, 2819–2831 (2011).

62. H. Bernard, J. Fjeldsa, M. Mohamed, A case study on the effects of disturbance and conversion of tropical lowland rain forest on the non-volant small mammals in north Borneo: management implications. *Mammal Study* **34**, 85–96 (2009).
63. N. J. Berry *et al.*, The high value of logged tropical forests: lessons from northern Borneo. *Biodivers. Conserv.* **19**, 985–997 (2010).
64. J. Bicknell, C. A. Peres, Vertebrate population responses to reduced-impact logging in a neotropical forest. *For. Ecol. Manage.* **259**, 2267–2275 (2010).
65. J. H. Bihn, M. Verhaagh, M. Braendle, R. Brandl, Do secondary forests act as refuges for old growth forest animals? Recovery of ant diversity in the Atlantic forest of Brazil. *Biol. Conserv.* **141**, 733–743 (2008).
66. R. Billeter *et al.*, Indicators for biodiversity in agricultural landscapes: a pan-European study. *J. Appl. Ecol.* **45**, 141–150 (2008).
67. R. J. Blake, D. B. Westbury, B. A. Woodcock, P. Sutton, S. G. Potts, Enhancing habitat to help the plight of the bumblebee. *Pest Manag. Sci.* **67**, 377–379 (2011).
68. K. R. Blanche, J. A. Ludwig, S. A. Cunningham, Proximity to rainforest enhances pollination and fruit set in orchards. *J. Appl. Ecol.* **43**, 1182–1187 (2006).
69. R. Blanche, S. A. Cunningham, Rain forest provides pollinating beetles for atemoya crops. *J. Econ. Entomol.* **98**, 1193–1201 (2005).
70. R. Bóçon, thesis, *Riqueza e abundância de aves em três estágios sucessionais da floresta ombrófila densa submontana, Antonina, Paraná*. (Hungarian Academy of Sciences, 2010).
71. P. A. V Borges *et al.*, Invasibility and species richness of island endemic arthropods: a general model of endemic vs. exotic species. *J. Biogeogr.* **33**, 169–187 (2006).
72. S. H. Borges, Bird assemblages in secondary forests developing after slash-and-burn agriculture in the Brazilian Amazon. *J. Trop. Ecol.* **23**, 469–477 (2007).
73. M. M. Bos, I. Steffan-Dewenter, T. Tscharntke, The contribution of cacao agroforests to the conservation of lower canopy ant and beetle diversity in Indonesia. *Biodivers. Conserv.* **16**, 2429–2444 (2007).
74. B. M. Bösing, D. H. Haarmeyer, J. Denger, J. U. Ganzhorn, U. Schmiedel, Effects of livestock grazing and habitat characteristics on small mammal communities in the Knersvlakte, South Africa. *J. Arid Environ.* **104**, 124–131 (2014).
75. C. Boutin, P. A. Martin, A. Baril, Arthropod diversity as affected by agricultural management (organic and conventional farming), plant species, and landscape context. *Ecoscience* **16**, 492–501 (2009).
76. J. Bouyer *et al.*, Identification of ecological indicators for monitoring ecosystem health in the trans-boundary W Regional park: A pilot study. *Biol. Conserv.* **138**, 73–88 (2007).
77. C. Bragagnolo, A. A. Nogueira, R. Pinto-da-Rocha, R. Pardini, Harvestmen in an Atlantic forest fragmented landscape: Evaluating assemblage response to habitat quality and quantity. *Biol. Conserv.* **139**, 389–400 (2007).
78. J. S. Brandt *et al.*, Sacred forests are keystone structures for forest bird conservation in southwest China's Himalayan Mountains. *Biol. Conserv.* **166**, 34–42 (2013).
79. F. Q. Brearley, Below-ground secondary succession in tropical forests of Borneo. *J. Trop. Ecol.* **27**, 413–420 (2011).
80. J. A. D. Breedt, N. Dreber, K. Kellner, Post-wildfire regeneration of rangeland productivity and functionality - observations across three semi-arid vegetation types in South Africa. *African J. Range Forage Sci.* **30**, 161–167 (2013).

81. I. Brito, M. J. Goss, M. de Carvalho, O. Chatagnier, D. van Tuinen, Impact of tillage system on arbuscular mycorrhiza fungal communities in the soil under Mediterranean conditions. *Soil Tillage Res.* **121**, 63–67 (2012).
82. J. Brunet *et al.*, Understory succession in post-agricultural oak forests: Habitat fragmentation affects forest specialists and generalists differently. *For. Ecol. Manage.* **262**, 1863–1871 (2011).
83. G. Buczkowski, Extreme life history plasticity and the evolution of invasive characteristics in a native ant. *Biol. Invasions*. **12**, 3343–3349 (2010).
84. G. Buczkowski, D. S. Richmond, The Effect of Urbanization on Ant Abundance and Diversity: A Temporal Examination of Factors Affecting Biodiversity. *PLoS One*. **7** (2012), doi:10.1371/journal.pone.0041729.
85. C. M. Buddle, D. P. Shorthouse, Effects of experimental harvesting on spider (Araneae) assemblages in boreal deciduous forests. *Can. Entomol.* **140**, 437–452 (2008).
86. E. Buscardo *et al.*, The early effects of afforestation on biodiversity of grasslands in Ireland. *Biodivers. Conserv.* **17**, 1057–1072 (2008).
87. J. Cabra-García, C. Bermúdez-Rivas, A. M. Osorio, P. Chacón, Cross-taxon congruence of alpha and beta diversity among five leaf litter arthropod groups in Colombia. *Biodivers. Conserv.* **21**, 1493–1508 (2012).
88. N. C. Cáceres, R. P. Nápoli, J. Casella, W. Hannibal, Mammals in a fragmented savannah landscape in south-western Brazil. *J. Nat. Hist.* **44**, 491–512 (2010).
89. N. L. Cagle, Snake species distributions and temperate grasslands: A case study from the American tallgrass prairie. *Biol. Conserv.* **141**, 744–755 (2008).
90. M. Calviño-Cancela, M. Rubido-Bará, E. J. B. van Etten, Do eucalypt plantations provide habitat for native forest biodiversity? *For. Ecol. Manage.* **270**, 153–162 (2012).
91. S. A. Cameron *et al.*, Patterns of widespread decline in North American bumble bees. *Proc. Natl. Acad. Sci. U. S. A.* **108**, 662–667 (2011).
92. D. Carpenter *et al.*, Biodiversity of soil macrofauna in the New Forest: a benchmark study across a national park landscape. *Biodivers. Conserv.* **21**, 3385–3410 (2012).
93. T. F. Carrijo, D. Brandao, D. E. de Oliveira, D. A. Costa, T. Santos, Effects of pasture implantation on the termite (Isoptera) fauna in the Central Brazilian Savanna (Cerrado). *J. Insect Conserv.* **13**, 575–581 (2009).
94. A. L. de Carvalho, E. J. L. Ferreira, J. M. T. Lima, A. L. de Carvalho, Floristic and structural comparisons among palm communities in primary and secondary forest fragments of the Raimundo Irineu Serra Environmental Protection Area - Rio Branco, Acre, Brazil. *Acta Amaz.* **40**, 657–666 (2010).
95. C. Cassano, J. Barlow, R. Pardini, Forest loss or management intensification? Identifying causes of mammal decline in cacao agroforests. *Biol. Conserv.* **169**, 14-22 (2014).
96. H. Castro, V. Lehsten, S. Lavorel, H. Freitas, Functional response traits in relation to land use change in the Montado. *Agric. Ecosyst. Environ.* **137**, 183–191 (2010).
97. A. A. Castro-Luna, V. J. Sosa, G. Castillo-Campos, Bat diversity and abundance associated with the degree of secondary succession in a tropical forest mosaic in south-eastern Mexico. *Anim. Conserv.* **10**, 219–228 (2007).
98. Center for International Forestry Research, *Multidisciplinary Landscape Assessment - Cameroon* (Center for International Forestry Research, 2013; http://www.cifor.org/mla/_ref/method/index.htm).

99. Center for International Forestry Research, *Multidisciplinary Landscape Assessment - Philippines* (Center for International Forestry Research, 2013; http://www.cifor.org/mla/_ref/method/index.htm).
100. A. Cerezo, M. C. Conde, S. L. Poggio, Pasture area and landscape heterogeneity are key determinants of bird diversity in intensively managed farmland. *Biodivers. Conserv.* **20**, 2649–2667 (2011).
101. K. A. Chapman, P. B. Reich, Land use and habitat gradients determine bird community diversity and abundance in suburban, rural and reserve landscapes of Minnesota, USA. *Biol. Conserv.* **135**, 527–541 (2007).
102. M. Chauvat, V. Wolters, J. Dauber, Response of collembolan communities to land-use change and grassland succession. *Ecography* **30**, 183–192 (2007).
103. M. Christensen, J. Heilmann-Clausen, Forest biodiversity gradients and the human impact in Annapurna Conservation Area, Nepal. *Biodivers. Conserv.* **18**, 2205–2221 (2009).
104. R. J. Clark, P. J. Gerard, J. M. Mellsop, Spider biodiversity and density following cultivation in pastures in the Waikato, New Zealand. *New Zeal. J. Agric. Res.* **47**, 247–259 (2004).
105. F. M. Clarke, L. V Rostant, P. A. Racey, Life after logging: post-logging recovery of a neotropical bat community. *J. Appl. Ecol.* **42**, 409–420 (2005).
106. D. F. R. Cleary *et al.*, Diversity and community composition of butterflies and odonates in an ENSO-induced fire affected habitat mosaic: a case study from East Kalimantan, Indonesia. *Oikos* **105**, 426–446 (2004).
107. D. F. R. Cleary, A. O. Mooers, Burning and logging differentially affect endemic vs. widely distributed butterfly species in Borneo. *Divers. Distrib.* **12**, 409–416 (2006).
108. K. L. Cockle, M. L. Leonard, A. A. Bodrati, Presence and abundance of birds in an Atlantic forest reserve and adjacent plantation of shade-grown yerba mate, in Paraguay. *Biodivers. Conserv.* **14**, 3265–3288 (2005).
109. S. Connop, T. Hill, J. Steer, P. Shaw, Microsatellite analysis reveals the spatial dynamics of Bombus humilis and Bombus sylvarum. *Insect Conserv. Divers.* **4**, 212–221 (2011).
110. M. D. Craig *et al.*, Does habitat structure influence capture probabilities? A study of reptiles in a eucalypt forest. *Wildl. Res.* **36**, 509–515 (2009).
111. M. D. Craig, A. H. Grigg, R. J. Hobbs, G. E. S. J. Hardy, Does coarse woody debris density and volume influence the terrestrial vertebrate community in restored bauxite mines? *For. Ecol. Manage.* **318**, 142–150 (2014).
112. M. D. Craig *et al.*, Identifying unidirectional and dynamic habitat filters to faunal recolonisation in restored mine-pits. *J. Appl. Ecol.* **49**, 919–928 (2012).
113. S. A. Cunningham, N. A. Schellhorn, A. Marcora, M. Batley, Movement and phenology of bees in a subtropical Australian agricultural landscape. *Austral Ecol.* **38**, 456–464 (2013).
114. P. G. da Silva, thesis, *Espécies de Scarabaeinae (Coleoptera: Scarabaeidae) de fragmentos florestais com diferentes níveis de alteração em Santa Maria, Rio Grande do Sul*. (Universidade Federal de Santa Maria, 2011).
115. B. D'Aniello, I. Stanislao, S. Bonelli, E. Balletto, Haying and grazing effects on the butterfly communities of two Mediterranean-area grasslands. *Biodivers. Conserv.* **20**, 1731–1744 (2011).
116. E. Danquah, S. K. Oppong, M. E. Nutsuakor, Effect of protected area category on mammal abundance in Western Ghana. *J. Biodivers. Environ. Sci.* **2**, 50–57 (2012).

117. B. Darvill, M. E. Knight, D. Goulson, Use of genetic markers to quantify bumblebee foraging range and nest density. *Oikos* **107**, 471–478 (2004).
118. A. L. V Davis, T. K. Philips, Effect of deforestation on a Southwest Ghana dung beetle assemblage (Coleoptera : Scarabaeidae) at the periphery of Ankasa conservation area. *Environ. Entomol.* **34**, 1081–1088 (2005).
119. J. Dawson *et al.*, Bird communities of the lower Waria Valley, Morobe Province, Papua New Guinea: a comparison between habitat types. *Trop. Conserv. Sci.* **4**, 317–348 (2011).
120. N. D’Cruze, S. Kumar, Effects of anthropogenic activities on lizard communities in northern Madagascar. *Anim. Conserv.* **14**, 542–552 (2011).
121. C. de Sassi, O. T. Lewis, J. M. Tylianakis, Plant-mediated and nonadditive effects of two global change drivers on an insect herbivore community. *Ecology*. **93**, 1892–1901 (2012).
122. V. M. de Souza, B. de Souza, E. F. Morato, Effect of the forest succession on the anurans (Amphibia: Anura) of the Reserve Catuaba and its periphery, Acre, southwestern Amazonia. *Rev. Bras. Zool.* **25**, 49–57 (2008).
123. B. de Thoisy *et al.*, Rapid evaluation of threats to biodiversity: human footprint score and large vertebrate species responses in French Guiana. *Biodivers. Conserv.* **19**, 1567–1584 (2010).
124. J. H. C. Delabie *et al.*, Ants as biological indicators of Wayana Amerindian land use in French Guiana. *C. R. Biol.* **332**, 673–684 (2009).
125. J. L. Devineau, A. Fournier, S. Nignan, “Ordinary biodiversity” in western Burkina Faso (West Africa): what vegetation do the state forests conserve? *Biodivers. Conserv.* **18**, 2075–2099 (2009).
126. T. Diekötter, K. Walther-Hellwig, M. Conradi, M. Suter, R. Frankl, Effects of landscape elements on the distribution of the rare bumblebee species Bombus muscorum in an agricultural landscape. *Biodivers. Conserv.* **15**, 57–68 (2006).
127. J. Dolia, M. S. Devy, N. A. Aravind, A. Kumar, Adult butterfly communities in coffee plantations around a protected area in the Western Ghats, India. *Anim. Conserv.* **11**, 26–34 (2008).
128. E. Domínguez, N. Bahamonde, C. Muñoz-Escobar, Efectos de la extracción de turba sobre la composición y estructura de una turbera de Sphagnum explotada y abandonada hace 20 años, Chile. *An. Inst. Patagon.* **40**, 37–45 (2012).
129. Y. Dominguez-Haydar, I. Armbrecht, Response of Ants and Their Seed Removal in Rehabilitation Areas and Forests at El Cerrejon Coal Mine in Colombia. *Restor. Ecol.* **19**, 178–184 (2010).
130. B. Dumont *et al.*, How does grazing intensity influence the diversity of plants and insects in a species-rich upland grassland on basalt soils? *Grass Forage Sci.* **64**, 92–105 (2009).
131. S. G. Dures, G. S. Cumming, The confounding influence of homogenising invasive species in a globally endangered and largely urban biome: Does habitat quality dominate avian biodiversity? *Biol. Conserv.* **143**, 768–777 (2010).
132. L. Edenius, G. Mikusinski, J. Bergh, Can repeated fertilizer applications to young Norway spruce enhance avian diversity in intensively managed forests? *Ambio* **40**, 521–527 (2011).
133. F. Eigenbrod, S. J. Hecnar, L. Fahrig, Accessible habitat: an improved measure of the effects of habitat loss and roads on wildlife populations. *Landsc. Ecol.* **23**, 159–168 (2008).

134. Z. Elek, G. L. Lovei, Patterns in ground beetle (Coleoptera: Carabidae) assemblages along an urbanisation gradient in Denmark. *Acta Oecologica-International J. Ecol.* **32**, 104–111 (2007).
135. W. Endo *et al.*, Game Vertebrate Densities in Hunted and Nonhunted Forest Sites in Manu National Park, Peru. *Biotropica* **42**, 251–261 (2010).
136. R. M. Ewers, S. Thorpe, R. K. Didham, Synergistic interactions between edge and area effects in a heavily fragmented landscape. *Ecology*. **88**, 96–106 (2007).
137. A. Faruk, D. Belabut, N. Ahmad, R. J. Knell, T. W. J. Garner, Effects of oil-palm plantations on diversity of tropical anurans. *Conserv. Biol.* **27**, 615–624 (2013).
138. N. Farwig *et al.*, Isolation from forest reduces pollination, seed predation and insect scavenging in Swiss farmland. *Landsc. Ecol.* **24**, 919–927 (2009).
139. N. Farwig, N. Sajita, K. Böhning-Gaese, Conservation value of forest plantations for bird communities in western Kenya. *For. Ecol. Manage.* **255**, 3885–3892 (2008).
140. T. M. Fayle *et al.*, Oil palm expansion into rain forest greatly reduces ant biodiversity in canopy, epiphytes and leaf-litter. *Basic Appl. Ecol.* **11**, 337–345 (2010).
141. R. J. Fensham, J. M. Dwyer, T. J. Eyre, R. J. Fairfax, J. Wang, The effect of clearing on plant composition in mulga (Acacia aneura) dry forest, Australia. *Austral Ecol.* **37**, 183–192 (2012).
142. H. Fermon, M. Waltert, R. I. Vane-Wright, M. Muhlenberg, Forest use and vertical stratification in fruit-feeding butterflies of Sulawesi, Indonesia: impacts for conservation. *Biodivers. Conserv.* **14**, 333–350 (2005).
143. I. C. Fernandez, J. A. Simonetti, Small mammal assemblages in fragmented shrublands of urban areas of Central Chile. *Urban Ecosyst.* **16**, 377–387 (2013).
144. C. Fiera, Preliminary data on the species diversity of Collembola (Hexapoda: Collembola) along an urban gradient in București. *Trav. du Museum Natl. d'Histoire Nat. "Grigore Antipa"* **51**, 363–367 (2008).
145. M. M. Fierro, L. Cruz-Lopez, D. Sanchez, R. Villanueva-Gutierrez, R. Vandame, Effect of Biotic Factors on the Spatial Distribution of Stingless Bees (Hymenoptera: Apidae, Meliponini) in Fragmented Neotropical Habitats. *Neotrop. Entomol.* **41**, 95–104 (2012).
146. B. K. C. Filgueiras, L. Iannuzzi, I. R. Leal, Habitat fragmentation alters the structure of dung beetle communities in the Atlantic Forest. *Biol. Conserv.* **144**, 362–369 (2011).
147. H. K. Firincioglu, S. S. Seefeldt, B. Sahin, M. Vural, Assessment of grazing effect on sheep fescue (*Festuca valesiaca*) dominated steppe rangelands, in the semi-arid Central Anatolian region of Turkey. *J. Arid Environ.* **73**, 1149–1157 (2009).
148. D. J. Flaspohler *et al.*, Long-term effects of fragmentation and fragment properties on bird species richness in Hawaiian forests. *Biol. Conserv.* **143**, 280–288 (2010).
149. R. E. Fowler, thesis, *An investigation into bee assemblage change along an urban-rural gradient*. (University of Birmingham, 2014).
150. M. Franzén, S. G. Nilsson, How can we preserve and restore species richness of pollinating insects on agricultural land? *Ecography* **31**, 698–708 (2008).
151. G. M. Fredriksson, L. S. Danielsen, J. E. Swenson, Impacts of El Niño related drought and forest fires on sun bear fruit resources in lowland dipterocarp forest of East Borneo. *Biodivers. Conserv.* **16**, 1823-1838 (2007).
152. G. D. Freire, P. C. Motta, Effects of experimental fire regimes on the abundance and diversity of cursorial arachnids of Brazilian savannah (cerrado biome). *J. Arachnol.* **39**, 263–272 (2011).

153. T. L. M. Frizzo, H. L. Vasconcelos, The potential role of scattered trees for ant conservation in an agriculturally dominated Neotropical landscape. *Biotropica* **45**, 644–651 (2013).
154. D. Fukuda, O. B. Tisen, K. Momose, S. Sakai, Bat diversity in the vegetation mosaic around a lowland dipterocarp forest of Borneo. *Raffles Bull. Zool.* **57**, 213–221 (2009).
155. D. Furlani, G. F. Ficetola, G. Colombo, M. Ugurlucan, F. De Bernardi, Deforestation and the structure of frog communities in the Humedale Terraba-Sierpe, Costa Rica. *Zoolog. Sci.* **26**, 197–202 (2009).
156. R. Gaigher, M. J. Samways, Surface-active arthropods in organic vineyards, integrated vineyards and natural habitat in the Cape Floristic Region. *J. Insect Conserv.* **14**, 595–605 (2010).
157. K. P. García, J. C. Ortiz Zapata, M. Aguayo, G. D'Elia, Assessing rodent community responses in disturbed environments of the Chilean Patagonia. *Mammalia* **77**, 195–204 (2013).
158. J. C. García-R, H. Cárdenas-H, F. Castro-H, Relationship between anurans diversity and successional stages of a very humid low montane forest in Valle del Cauca, southwestern of Colombia. *Caldasia*. **29**, 363–374 (2007).
159. J. G. Garden, C. A. McAlpine, H. P. Possingham, Multi-scaled habitat considerations for conserving urban biodiversity: native reptiles and small mammals in Brisbane, Australia. *Landsc. Ecol.* **25**, 1013–1028 (2010).
160. T. A. Gardner, M. I. M. Hernández, J. Barlow, C. A. Peres, Understanding the biodiversity consequences of habitat change: the value of secondary and plantation forests for neotropical dung beetles. *J. Appl. Ecol.* **45**, 883–893 (2008).
161. T. A. Gardner *et al.*, The value of primary, secondary, and plantation forests for a Neotropical Herpetofauna. *Conserv. Biol.* **21**, 775–787 (2007).
162. A. Garmendia, V. Arroyo-Rodriguez, A. Estrada, E. J. Naranjo, K. E. Stoner, Landscape and patch attributes impacting medium- and large-sized terrestrial mammals in a fragmented rain forest. *J. Trop. Ecol.* **29**, 331–344 (2013).
163. E. Gaublomme, F. Hendrickx, H. Dhuyvetter, K. Desender, The effects of forest patch size and matrix type on changes in carabid beetle assemblages in an urbanized landscape. *Biol. Conserv.* **141**, 2585–2596 (2008).
164. B. M. Ge *et al.*, Communities of soil macrofauna in green spaces of an urbanizing city at east China. *Rev. Chil. Hist. Nat.* **85**, 219–226 (2012).
165. B. Gendreau-Berthiaume, D. D. Kneeshaw, B. D. Harvey, Effects of partial cutting and partial disturbance by wind and insects on stand composition, structure and growth in boreal mixedwoods. *Forestry*. **85**, 551–565 (2012).
166. C. Gheler-Costa, C. A. Vettorazzi, R. Pardini, L. M. Verdade, The distribution and abundance of small mammals in agroecosystems of southeastern Brazil. *Mammalia* **76**, 185–191 (2012).
167. P. Giordani, Assessing the effects of forest management on epiphytic lichens in coppiced forests using different indicators. *Plant Biosyst.* **146**, 628–637 (2012).
168. P. Giordani *et al.*, Land use intensity drives the local variation of lichen diversity in Mediterranean ecosystems sensitive to desertification. *Bibl. Lichenol.* **105**, 139–148 (2010).
169. S. Giordano *et al.*, Biodiversity and trace element content of epiphytic bryophytes in urban and extraurban sites of southern Italy. *Plant Ecol.* **170**, 1–14 (2004).

170. C. Golodets, J. Kigel, M. Sternberg, Recovery of plant species composition and ecosystem function after cessation of grazing in a Mediterranean grassland. *Plant Soil*. **329**, 365–378 (2010).
171. L. G. L. Gomes, V. Oostra, V. Nijman, A. M. Cleef, M. Kappelle, Tolerance of frugivorous birds to habitat disturbance in a tropical cloud forest. *Biol. Conserv.* **141**, 860–871 (2008).
172. M. S. Gottschalk, D. C. De Toni, V. L. S. Valente, P. R. P. Hofmann, Changes in Brazilian Drosophilidae (Diptera) assemblages across an urbanisation gradient. *Neotrop. Entomol.* **36**, 848–62 (2007).
173. R. K. Gould *et al.*, Forest restoration and parasitoid wasp communities in montane Hawai'i. *PLoS One* **8**, e59356 (2013), doi:10.1371/journal.pone.0059356.
174. D. Goulson *et al.*, Effects of land use at a landscape scale on bumblebee nest density and survival. *J. Appl. Ecol.* **47**, 1207–1215 (2010).
175. D. Goulson, G. C. Lye, B. Darvill, Diet breadth, coexistence and rarity in bumblebees. *Biodivers. Conserv.* **17**, 3269–3288 (2008).
176. A. D. Gove, J. D. Majer, V. Rico-Gray, Methods for conservation outside of formal reserve systems: The case of ants in the seasonally dry tropics of Veracruz, Mexico. *Biol. Conserv.* **126**, 328–338 (2005).
177. L. Granjon, J. M. Duplantier, Guinean biodiversity at the edge: Rodents in forest patches of southern Mali. *Mamm. Biol.* **76**, 583–591 (2011).
178. I. Grass, D. G. Berens, F. Peter, N. Farwig, Additive effects of exotic plant abundance and land-use intensity on plant-pollinator interactions. *Oecologia* **173**, 913–923 (2013).
179. C. L. Gray, E. M. Slade, D. J. Mann, O. T. Lewis, Do riparian reserves support dung beetle biodiversity and ecosystem services in oil palm-dominated tropical landscapes? *Ecol. Evol.* **4**, 1049–1060 (2014).
180. W.-B. Gu, Y. Zhen-Rong, H. Dun-Xiao, Carabid community and its fluctuation in farmland of salinity transforming area in the North China Plain: a case study in Quzhou County, Hebei Province. *Biodivers. Sci.* **12**, 262–268 (2004).
181. N. R. Gunawardene, J. D. Majer, J. P. Edirisinghe, Investigating residual effects of selective logging on ant species assemblages in Sinharaja Forest Reserve, Sri Lanka. *For. Ecol. Manage.* **259**, 555–562 (2010).
182. A. G. Gutierrez *et al.*, Structural and environmental characterization of old-growth temperate rainforests of northern Chiloe Island, Chile: Regional and global relevance. *For. Ecol. Manage.* **258**, 376–388 (2009).
183. D. L. Gutierrez-Lamus, Composition and abundance of Anura in two forest types (natural and planted) in the eastern Cordillera of Colombia. *Caldasia* **26**, 245–264 (2004).
184. D. H. Haarmeyer, U. Schmiedel, J. Dengler, B. M. Bosing, How does grazing intensity affect different vegetation types in arid Succulent Karoo, South Africa? Implications for conservation management. *Biol. Conserv.* **143**, 588–596 (2010).
185. N. R. Hashim, W. F. Akmal, W. Jusoh, M. Nasir, Ant diversity in a Peninsular Malaysian mangrove forest and oil palm plantation. *Asian Myrmecology* **3**, 5–8 (2010).
186. S. N. Hassan *et al.*, Human-induced Disturbances Influence on Bird Communities of Coastal Forests in Eastern Tanzania. *Br. J. Appl. Sci. Technol.* **3**, 48–64 (2013).
187. R. G. Hatfield, G. LeBuhn, Patch and landscape factors shape community assemblage of bumble bees, *Bombus* spp. (Hymenoptera: Apidae), in montane meadows. *Biol. Conserv.* **139**, 150–158 (2007).

188. J. Hawes *et al.*, Diversity and composition of Amazonian moths in primary, secondary and plantation forests. *J. Trop. Ecol.* **25**, 281–300 (2009).
189. A. J. Helden, S. R. Leather, Biodiversity on urban roundabouts - Hemiptera, management and the species-area relationship. *Basic Appl. Ecol.* **5**, 367–377 (2004).
190. L. Hernández, L. Delgado, W. Meier, C. Duran, Empobrecimiento de bosques fragmentados en el norte de la Gran Sabana, Venezuela. *Interciencia*. **37**, 891–898 (2012).
191. P. Hietz, Conservation of vascular epiphyte diversity in Mexican coffee plantations. *Conserv. Biol.* **19**, 391–399 (2005).
192. D. Higuera, J. H. D. Wolf, Vascular epiphytes in dry oak forests show resilience to anthropogenic disturbance, Cordillera Oriental, Colombia. *Caldasia* **32**, 161–174 (2010).
193. B. Hilje, T. M. Aide, Recovery of amphibian species richness and composition in a chronosequence of secondary forests, northeastern Costa Rica. *Biol. Conserv.* **146**, 170–176 (2012).
194. A. Hoffmann, U. Zeller, Influence of variations in land use intensity on species diversity and abundance of small mammals in the Nama Karoo, Namibia. *Belgian J. Zool.* **135**, 91–96 (2005).
195. F. G. Horgan, Invasion and retreat: shifting assemblages of dung beetles amidst changing agricultural landscapes in central Peru. *Biodivers. Conserv.* **18**, 3519–3541 (2009).
196. E. Hornung, B. Tothmeresz, T. Magura, F. Vilisics, Changes of isopod assemblages along an urban-suburban-rural gradient in Hungary. *Eur. J. Soil Biol.* **43**, 158–165 (2007).
197. C. Hu, Z. P. Cao, Nematode community structure under compost and chemical fertilizer management practice, in the north China plain. *Exp. Agric.* **44**, 485–496 (2008).
198. K. Hylander, C. Nilsson, T. Gothner, Effects of buffer-strip retention and clearcutting on land snails in boreal riparian forests. *Conserv. Biol.* **18**, 1052–1062 (2004).
199. K. Hylander, H. Weibull, Do time-lagged extinctions and colonizations change the interpretation of buffer strip effectiveness? - a study of riparian bryophytes in the first decade after logging. *J. Appl. Ecol.* **49**, 1316–1324 (2012).
200. K. Hylander, S. Nemomissa, Complementary roles of home gardens and exotic tree plantations as alternative habitats for plants of the Ethiopian montane rainforest. *Conserv. Biol.* **23**, 400–409 (2009).
201. R. A. Ims, J. A. Henden, Collapse of an arctic bird community resulting from ungulate-induced loss of erect shrubs. *Biol. Conserv.* **149**, 2–5 (2012).
202. P. J. Isaacs-Cubides, J. N. Urbina-Cardona, Anthropogenic disturbance and edge effects on anuran assemblages inhabiting cloud forest fragments in Colombia. *Nat. Conserv.* **9**, 39–46 (2011).
203. M. Ishitani, D. J. Kotze, J. Niemela, Changes in carabid beetle assemblages across an urban-rural gradient in Japan. *Ecography* **26**, 481–489 (2003).
204. C. T. Jacobs, C. H. Scholtz, F. Escobar, A. L. V Davis, How might intensification of farming influence dung beetle diversity (Coleoptera: Scarabaeidae) in Maputo Special Reserve (Mozambique)? *J. Insect Conserv.* **14**, 389–399 (2010).
205. G. Jalilova, J. de Groot, H. Vacik, Evaluating the effects of habitats on birds in the walnut fruit forests: a case study from Kyrgyzstan. *Biodiversity* **14**, 97–110 (2013).
206. M. F. Johnson, A. Gómez, M. Pinedo-Vasquez, Land use and mosquito diversity in the Peruvian Amazon. *J. Med. Entomol.* **45**, 1023–1030 (2008).
207. V. Jolli, M. K. Pandit, Monitoring pheasants (Phasianidae) in the western Himalayas to measure the impact of hydro-electric projects. *Ring* **33**, 37–46 (2011).

208. M. Jonsell, Old park trees as habitat for saproxylic beetle species. *Biodivers. Conserv.* **21**, 619–642 (2012).
209. L. Joubert, K. J. Esler, S. D. J. Privett, The effect of ploughing and augmenting natural vegetation with commercial fynbos species on the biodiversity of Overberg Sandstone fynbos on the Agulhas Plain, South Africa. *South African J. Bot.* **75**, 526–531 (2009).
210. H. E. Julier, T. H. Roulston, Wild bee abundance and pollination service in cultivated pumpkins: farm management, nesting behavior and landscape effects. *J. Econ. Entomol.* **102**, 563–573 (2009).
211. T. S. Jung, T. Powell, Spatial distribution of meadow jumping mice (*Zapus hudsonius*) in logged boreal forest of northwestern Canada. *Mamm. Biol.* **76**, 678–682 (2011).
212. V. Kapoor, Effects of rainforest fragmentation and shade-coffee plantations on spider communities in the Western Ghats, India. *J. Insect Conserv.* **12**, 53–68 (2008).
213. H. Kappes, L. Katzschner, C. Nowak, Urban summer heat load: meteorological data as a proxy for metropolitan biodiversity. *Meteorol. Zeitschrift* **21**, 525–528 (2012).
214. V. Kati, K. Zografou, E. Tzirkalli, T. Chitos, L. Willemse, Butterfly and grasshopper diversity patterns in humid Mediterranean grasslands: the roles of disturbance and environmental factors. *J. Insect Conserv.* **16**, 807–818 (2012).
215. E. Katovai, A. L. Burley, M. M. Mayfield, Understory plant species and functional diversity in the degraded wet tropical forests of Kolombangara Island, Solomon Islands. *Biol. Conserv.* **145**, 214–224 (2012).
216. F. Kazerani, K. S., I. Grichanov, Diversity of the genus *Dolichopus* Latreille in three different habitats of East Azerbaijan Province, with new records for Iran. *Arxius de Miscel·lània Zoològica* **11**, 134–152 (2013).
217. M. Kessler *et al.*, Tree diversity in primary forest and different land use systems in Central Sulawesi, Indonesia. *Biodivers. Conserv.* **14**, 547–560 (2005).
218. M. Kessler *et al.*, Alpha and beta diversity of plants and animals along a tropical land-use gradient. *Ecol. Appl.* **19**, 2142–56 (2009).
219. A. M. Kittle, A. C. Watson, P. H. Chanaka Kumara, H. K. Nimalka Sanjeewani, Status and distribution of the leopard in the central hills of Sri Lanka. *Cat News*. **56**, 28–31 (2012).
220. F. Kohler, J. Verhulst, R. van Klink, D. Kleijn, At what spatial scale do high-quality habitats enhance the diversity of forbs and pollinators in intensively farmed landscapes? *J. Appl. Ecol.* **45**, 753–762 (2008).
221. M. Koivula, V. Hyyrylainen, E. Soininen, Carabid beetles (Coleoptera: Carabidae) at forest-farmland edges in southern Finland. *J. Insect Conserv.* **8**, 297–309 (2004).
222. A. Kolb, M. Diekmann, Effects of environment, habitat configuration and forest continuity on the distribution of forest plant species. *J. Veg. Sci.* **15**, 199–208 (2004).
223. Á. Kőrösi, P. Batáry, A. Orosz, D. Rédei, A. Báldi, Effects of grazing, vegetation structure and landscape complexity on grassland leafhoppers (Hemiptera: Auchenorrhyncha) and true bugs (Hemiptera: Heteroptera) in Hungary. *Insect Conserv. Divers.* **5**, 57–66 (2012).
224. J. Krauss, A. M. Klein, I. Steffan-Dewenter, T. Tscharntke, Effects of habitat area, isolation, and landscape diversity on plant species richness of calcareous grasslands. *Biodivers. Conserv.* **13**, 1427–1439 (2004).
225. J. Krauss, I. Steffan-Dewenter, T. Tscharntke, How does landscape context contribute to effects of habitat fragmentation on diversity and population density of butterflies? *J. Biogeogr.* **30**, 889–900 (2003).

226. J. Krauss *et al.*, Habitat fragmentation causes immediate and time-delayed biodiversity loss at different trophic levels. *Ecol. Lett.* **13**, 597–605 (2010).
227. R. Kumar, G. Shahabuddin, Effects of biomass extraction on vegetation structure, diversity and composition of forests in Sariska Tiger Reserve, India. *Environ. Conserv.* **32**, 248–259 (2005).
228. D. J. Kurz, A. J. Nowakowski, M. W. Tingley, M. A. Donnelly, D. S. Wilcove, Forest-land use complementarity modifies community structure of a tropical herpetofauna. *Biol. Conserv.* **170**, 246–255 (2014).
229. A. S. Kutt, E. P. Vanderduys, P. O'Reagain, Spatial and temporal effects of grazing management and rainfall on the vertebrate fauna of a tropical savanna. *Rangel. J.* **34**, 173–182 (2012).
230. A. S. Kutt, J. C. Z. Woinarski, The effects of grazing and fire on vegetation and the vertebrate assemblage in a tropical savanna woodland in north-eastern Australia. *J. Trop. Ecol.* **23**, 95–106 (2007).
231. T. Lachat *et al.*, Arthropod diversity in Lama forest reserve (South Benin), a mosaic of natural, degraded and plantation forests. *Biodivers. Conserv.* **15**, 3–23 (2006).
232. M. V Lantschner, V. Rusch, J. P. Hayes, Habitat use by carnivores at different spatial scales in a plantation forest landscape in Patagonia, Argentina. *For. Ecol. Manage.* **269**, 271–278 (2012).
233. M. V Lantschner, V. Rusch, C. Peyrou, Bird assemblages in pine plantations replacing native ecosystems in NW Patagonia. *Biodivers. Conserv.* **17**, 969–989 (2008).
234. S. C. Latta, B. A. Tinoco, P. X. Astudillo, C. H. Graham, Patterns and magnitude of temporal change in avian communities in the Ecuadorian Andes. *Condor* **113**, 24–40 (2011).
235. J.-P. Légaré, C. Hébert, J.-C. Ruel, Alternative Silvicultural Practices in Irregular Boreal Forests: Response of Beetle Assemblages. *Silva Fenn.* **45**, 937–956 (2011).
236. V. Lehouck *et al.*, Habitat disturbance reduces seed dispersal of a forest interior tree in a fragmented African cloud forest. *Oikos* **118**, 1023–1034 (2009).
237. P. E. Lentini, T. G. Martin, P. Gibbons, J. Fischer, S. A. Cunningham, Supporting wild pollinators in a temperate agricultural landscape: Maintaining mosaics of natural features and production. *Biol. Conserv.* **149**, 84–92 (2012).
238. S. G. Letcher, R. L. Chazdon, Rapid recovery of biomass, species richness, and species composition in a forest chronosequence in Northeastern Costa Rica. *Biotropica* **41**, 608–617 (2009).
239. S. N. Li, F. S. Zou, Q. Zhang, F. H. Sheldon, Species richness and guild composition in rubber plantations compared to secondary forest on Hainan Island, China. *Agrofor. Syst.* **87**, 1117–1128 (2013).
240. L. H. Liow, N. S. Sodhi, T. Elmqvist, Bee diversity along a disturbance gradient in tropical lowland forests of south-east Asia. *J. Appl. Ecol.* **38**, 180–192 (2001).
241. S. A. Litchwark, thesis, *Honeybee declines in a changing landscape: interactive effects of honeybee declines and land-use intensification on pollinator communities*. (University of Canterbury, 2013).
242. N. A. Littlewood, Grazing impacts on moth diversity and abundance on a Scottish upland estate. *Insect Conserv. Divers.* **1**, 151–160 (2008).
243. N. A. Littlewood, R. J. Pakeman, G. Pozsgai, Grazing impacts on Auchenorrhyncha diversity and abundance on a Scottish upland estate. *Insect Conserv. Divers.* **5**, 67–74 (2012).

244. Y. H. Liu, J. C. Axmacher, C. L. Wang, L. T. Li, Z. R. Yu, Ground beetle (Coleoptera: Carabidae) assemblages of restored semi-natural habitats and intensively cultivated fields in northern China. *Restor. Ecol.* **20**, 234–239 (2012).
245. N. F. Lo-Man-Hung, T. A. Gardner, M. A. Ribeiro-Júnior, J. Barlow, A. B. Bonaldo, The value of primary, secondary, and plantation forests for Neotropical epigeic arachnids. *J. Arachnol.* **36**, 394–401 (2008).
246. N. F. Lo-Man-Hung *et al.*, Impact of different land management on soil spiders (Arachnida: Araneae) in two Amazonian areas of Brazil and Colombia. *J. Arachnol.* **39**, 296–302 (2011).
247. C. A. López-Quintero, G. Straatsma, A. E. Franco-Molano, T. Boekhout, Macrofungal diversity in Colombian Amazon forests varies with regions and regimes of disturbance. *Biodivers. Conserv.* **21**, 2221–2243 (2012).
248. M. Louhaichi, A. K. Salkini, S. L. Petersen, Effect of small ruminant grazing on the plant community characteristics of semiarid Mediterranean ecosystems. *Int. J. Agric. Biol.* **11**, 681–689 (2009).
249. M. E. Lucas-Borja *et al.*, The effects of human trampling on the microbiological properties of soil and vegetation in Mediterranean mountain areas. *Land Degrad. Dev.* **22**, 383–394 (2011).
250. V. H. Luja, S. Herrando-Perez, D. Gonzalez-Solis, L. Luiselli, Secondary rain forests are not havens for reptile species in tropical Mexico. *Biotropica* **40**, 747–757 (2008).
251. R. Macip-Ríos, A. Muñoz–Alonso, Diversidad de lagartijas en cafetales y bosque primario en el Soconusco chiapaneco. *Rev. Mex. Biodivers.* **79**, 185–195 (2008).
252. M. C. G. MacSwiney, P. L. Vilchis, F. M. Clarke, P. A. Racey, The importance of cenotes in conserving bat assemblages in the Yucatan, Mexico. *Biol. Conserv.* **136**, 499–509 (2007).
253. K. Maeto, S. Sato, Impacts of forestry on ant species richness and composition in warm-temperate forests of Japan. *For. Ecol. Manage.* **187**, 213–223 (2004).
254. T. Magura, R. Horvath, B. Tothmeresz, Effects of urbanization on ground-dwelling spiders in forest patches, in Hungary. *Landsc. Ecol.* **25**, 621–629 (2010).
255. N. A. D. Mallari *et al.*, Population densities of understorey birds across a habitat gradient in Palawan, Philippines: implications for conservation. *Oryx* **45**, 234–242 (2011).
256. L. Malone *et al.*, Observations on bee species visiting white clover in New Zealand pastures. *J. Apic. Res.* **49**, 284–286 (2010).
257. P. K. Malonza, M. Veith, Amphibian community along elevational and habitat disturbance gradients in the Taita Hills, Kenya. *Herpetotropicos* **7**, 7-16 (2012).
258. J. Malumbres-Olarte *et al.*, Big and aerial invaders: dominance of exotic spiders in burned New Zealand tussock grasslands. *Biol. Invasions*. **16**, 2311–2322 (2014).
259. E. Marin-Spiotta, R. Ostertag, W. L. Silver, Long-term patterns in tropical reforestation: plant community composition and aboveground biomass accumulation. *Ecol. Appl.* **17**, 828–839 (2007).
260. C. Marsh, thesis, *Community-level modelling of α-, β- and γ-diversity of multiple taxa: birds and butterflies on Anjouan, Comoros Islands*. (Imperial College London, 2005).
261. C. J. Marsh, O. T. Lewis, I. Said, R. M. Ewers, Community-level diversity modelling of birds and butterflies on Anjouan, Comoro Islands. *Biol. Conserv.* **143**, 1364–1374 (2010).

262. E. J. P. Marshall, T. M. West, D. Kleijn, Impacts of an agri-environment field margin prescription on the flora and fauna of arable farmland in different landscapes. *Agric. Ecosyst. Environ.* **113**, 36–44 (2006).
263. P. S. Martin, C. Gheler-Costa, P. C. Lopes, L. M. Rosalino, L. M. Verdade, Terrestrial non-volant small mammals in agro-silvicultural landscapes of Southeastern Brazil. *For. Ecol. Manage.* **282**, 185–195 (2012).
264. T. Matsumoto, T. Itioka, S. Yamane, K. Momose, Traditional land use associated with swidden agriculture changes encounter rates of the top predator, the army ant, in Southeast Asian tropical rain forests. *Biodivers. Conserv.* **18**, 3139–3151 (2009).
265. M. M. Mayfield, D. Ackerly, G. C. Daily, The diversity and conservation of plant reproductive and dispersal functional traits in human-dominated tropical landscapes. *J. Ecol.* **94**, 522–536 (2006).
266. J. L. McCarthy, K. P. McCarthy, T. K. Fuller, T. M. McCarthy, Assessing variation in wildlife biodiversity in the Tien Shan Mountains of Kyrgyzstan using ancillary camera-trap photos. *Mt. Res. Dev.* **30**, 295–301 (2010).
267. Q. S. McFrederick, G. LeBuhn, Are urban parks refuges for bumble bees *Bombus* spp. (Hymenoptera: Apidae)? *Biol. Conserv.* **129**, 372–382 (2006).
268. S. McNamara, P. D. Erskine, D. Lamb, L. Chantalangsy, S. Boyle, Primary tree species diversity in secondary fallow forests of Laos. *For. Ecol. Manage.* **281**, 93–99 (2012).
269. W. J. McShea *et al.*, The importance of secondary forest blocks for terrestrial mammals within an *Acacia*/secondary forest matrix in Sarawak, Malaysia. *Biol. Conserv.* **142**, 3108–3119 (2009).
270. S. S. Meijer, R. J. Whittaker, P. A. V Borges, The effects of land-use change on arthropod richness and abundance on Santa Maria Island (Azores): unmanaged plantations favour endemic beetles. *J. Insect Conserv.* **15**, 505–522 (2011).
271. B. Meyer, V. Gaebele, I. D. Steffan-Dewenter, Patch size and landscape effects on pollinators and seed set of the horseshoe vetch, hippocrepis comosa, in an agricultural landscape of central Europe. *Entomol. Gen.* **30**, 173–185 (2007).
272. B. Meyer, F. Jauker, I. Steffan-Dewenter, Contrasting resource-dependent responses of hoverfly richness and density to landscape structure. *Basic Appl. Ecol.* **10**, 178–186 (2009).
273. E. Mico, A. Garcia-Lopez, H. Brustel, A. Padilla, E. Galante, Explaining the saproxylic beetle diversity of a protected Mediterranean area. *Biodivers. Conserv.* **22**, 889–904 (2013).
274. J. C. Milder *et al.*, Effects of farm and landscape management on bird and butterfly conservation in western Honduras. *Ecosphere* **1**, art2 (2010).
275. M. V. Miranda, N. Politi, L. O. Rivera, Unexpected changes in the bird assemblage in areas under selective logging in piedmont forest in northwestern Argentina. *Ornitol. Neotrop.* **21**, 323–337 (2010).
276. M. L. Moir, K. E. C. Brennan, J. M. Koch, J. D. Majer, M. J. Fletcher, Restoration of a forest ecosystem: The effects of vegetation and dispersal capabilities on the reassembly of plant-dwelling arthropods. *For. Ecol. Manage.* **217**, 294–306 (2005).
277. D. Moreno-Mateos *et al.*, Effects of land use on nocturnal birds in a Mediterranean agricultural landscape. *Acta Ornithol.* **46**, 173–182 (2011).
278. M. N. Muchane *et al.*, Land use practices and their implications on soil macro-fauna in Maasai Mara ecosystem. *Int. J. Biodivers. Conserv.* **4**, 500–514 (2012).

279. S. Mudri-Stojnic, A. Andric, Z. Jozan, A. Vujic, Pollinator diversity (Hymenoptera and Diptera) in semi-natural habitats in Serbia during summer. *Arch. Biol. Sci.* **64**, 777–786 (2012).
280. F. B. Munyekenye, E. M. Mwangi, N. N. Gichuki, Bird species richness and abundance in different forest types at Kakamega Forest, western Kenya. *Ostrich* **79**, 37–42 (2008).
281. R. Naidoo, Species richness and community composition of songbirds in a tropical forest-agricultural landscape. *Anim. Conserv.* **7**, 93–105 (2004).
282. A. Naithani, D. Bhatt, Bird community structure in natural and urbanized habitats along an altitudinal gradient in Pauri district (Garhwal Himalaya) of Uttarakhand state, India. *Biologia* **67**, 800–808 (2012).
283. A. Nakamura, H. Proctor, C. P. Catterall, Using soil and litter arthropods to assess the state of rainforest restoration. *Ecol. Manag. Restor.* **4**, S20–S28 (2003).
284. Y. Nakashima, E. Inoue, E. F. Akomo-Okoue, Population density and habitat preferences of forest duikers in Moukalaba-Doudou National Park, Gabon. *African Zool.* **48**, 395–399 (2013).
285. S. Naoe, S. Sakai, T. Masaki, Effect of forest shape on habitat selection of birds in a plantation-dominant landscape across seasons: comparison between continuous and strip forests. *J. For. Res.* **17**, 219–223 (2012).
286. D. Navarrete, G. Halffter, Dung beetle (Coleoptera: Scarabaeidae: Scarabaeinae) diversity in continuous forest, forest fragments and cattle pastures in a landscape of Chiapas, Mexico: the effects of anthropogenic changes. *Biodivers. Conserv.* **17**, 2869–2898 (2008).
287. I. L. Navarro, A. K. Roman, F. H. Gomez, H. A. Perez, Seasonal variation in dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) from Serrania de Coraza, Sucre (Colombia). *Rev. Colomb. Cienc. Anim.* **3**, 102–110 (2011).
288. P. K. Ndang'ang'a, J. B. M. Njoroge, M. Githiru, Vegetation composition and structure influences bird species community assemblages in the highland agricultural landscape of Nyandarua, Kenya. *Ostrich* **84**, 171–179 (2013).
289. E. L. Neuschulz, A. Botzat, N. Farwig, Effects of forest modification on bird community composition and seed removal in a heterogeneous landscape in South Africa. *Oikos* **120**, 1371-1379 (2011).
290. V. Nicolas, P. Barriere, A. Tapiero, M. Colyn, Shrew species diversity and abundance in Ziama Biosphere Reserve, Guinea: comparison among primary forest, degraded forest and restoration plots. *Biodivers. Conserv.* **18**, 2043–2061 (2009).
291. A. Nielsen *et al.*, Assessing bee species richness in two Mediterranean communities: importance of habitat type and sampling techniques. *Ecol. Res.* **26**, 969–983 (2011).
292. N. Noreika, D. J. Kotze, Forest edge contrasts have a predictable effect on the spatial distribution of carabid beetles in urban forests. *J. Insect Conserv.* **16**, 867–881 (2012).
293. N. Noreika, New records of rare species of Coleoptera found in Ukmergė district in 2004-2005. *New Rare Lith. Insect Species*. **21**, 68–71 (2009).
294. O. Norfolk, M. Abdel-Dayem, F. Gilbert, Rainwater harvesting and arthropod biodiversity within an arid agro-ecosystem. *Agric. Ecosyst. Environ.* **162**, 8–14 (2012).
295. O. Norfolk, M. P. Eichhorn, F. Gilbert, Traditional agricultural gardens conserve wild plants and functional richness in arid South Sinai. *Basic Appl. Ecol.* **14**, 659–669 (2013).
296. J. A. Noriega, E. Realpe, G. Fagua, Diversidad de escarabajos coprofagos (Coleoptera: Scarabaeidae) en un bosque de galeria con tres estadios de alteracion. *Univ. Sci.* **12**, 51–63 (2007).

297. J. A. Noriega, J. M. Palacio, J. D. Monroy-G, E. Valencia, Estructura de un ensamblaje de escarabajos coprofagos (Coleoptera: Scarabaeinae) en tres sitios con diferente uso del suelo en Antioquia, Colombia. *Actual. Biol.* **34**, 43–54 (2012).
298. D. A. Norton, P. R. Espie, W. Murray, J. Murray, Influence of pastoral management on plant biodiversity in a depleted short tussock grassland, Mackenzie Basin. *N. Z. J. Ecol.* **30**, 335–344 (2006).
299. N. M. Nöske *et al.*, Disturbance effects on diversity of epiphytes and moths in a montane forest in Ecuador. *Basic Appl. Ecol.* **9**, 4–12 (2008).
300. C. Numa, J. R. Verdu, C. Rueda, E. Galante, Comparing dung beetle species assemblages between protected areas and adjacent pasturelands in a Mediterranean savanna landscape. *Rangel. Ecol. Manag.* **65**, 137–143 (2012).
301. T. G. O'Connor, Influence of land use on plant community composition and diversity in Highland Sourveld grassland in the southern Drakensberg, South Africa. *J. Appl. Ecol.* **42**, 975–988 (2005).
302. N. O'Dea, R. J. Whittaker, How resilient are Andean montane forest bird communities to habitat degradation? *Biodivers. Conserv.* **16**, 1131–1159 (2007).
303. S. Oertli, A. Muller, S. Dorn, Ecological and seasonal patterns in the diversity of a species-rich bee assemblage (Hymenoptera: Apoidea: Apiformes). *Eur. J. Entomol.* **102**, 53–63 (2005).
304. P. J. O'Farrell, J. S. Donaldson, M. T. Hoffman, A. D. Mader, Small mammal diversity and density on the Bokkeveld escarpment, South Africa - implications for conservation and livestock predation. *African Zool.* **43**, 117–124 (2008).
305. C. Ofori-Boateng *et al.*, Differences in the effects of selective logging on amphibian assemblages in three West African forest types. *Biotropica* **45**, 94–101 (2013).
306. C. Oke, Land snail diversity in post extraction secondary forest reserves in Edo State, Nigeria. *Afr. J. Ecol.* **51**, 244–254 (2013).
307. O. C. Oke, J. U. Chokor, The effect of land use on snail species richness and diversity in the tropical rainforest of south-western Nigeria. *African Sci.* **10**, 95–108 (2009).
308. D. E. Oliveira, T. F. Carrijo, D. Brandão, Species composition of termites (Isoptera) in different Cerrado vegetation physiognomies. *Sociobiology* **60**, 190–197 (2013).
309. L. M. Osgathorpe, K. Park, D. Goulson, The use of off-farm habitats by foraging bumblebees in agricultural landscapes: implications for conservation management. *Apidologie* **43**, 113–127 (2012).
310. S. E. Otavo, A. Parrado-Rosselli, J. A. Noriega, Scarabaeoidea superfamily (Insecta: Coleoptera) as a bioindicator element of anthropogenic disturbance in an Amazon national park. *Rev. Biol. Trop.* **61**, 735–752 (2013).
311. C. R. V. Otto, G. J. Roloff, Songbird response to green-tree retention prescriptions in clearcut forests. *For. Ecol. Manage.* **284**, 241–250 (2012).
312. Ö. Özden, W. M. Ciesla, W. J. Fuller, D. J. Hodgson, Butterfly diversity in Mediterranean islands and in Pentadaktylos *Pinus brutia* forests of Cyprus. *Biodivers. Conserv.* **17**, 2821–2832 (2008).
313. N. V. Page, Q. Qureshi, G. S. Rawat, C. G. Kushalappa, Plant diversity in sacred forest fragments of Western Ghats: a comparative study of four life forms. *Plant Ecol.* **206**, 237–250 (2010).

314. S. Paradis, T. T. Work, Partial cutting does not maintain spider assemblages within the observed range of natural variability in Eastern Canadian black spruce forests. *For. Ecol. Manage.* **262**, 2079–2093 (2011).
315. J. Paritsis, M. A. Aizen, Effects of exotic conifer plantations on the biodiversity of understory plants, epigeal beetles and birds in *Nothofagus dombeyi* forests. *For. Ecol. Manage.* **255**, 1575–1583 (2008).
316. A. Parra-H, G. Nates-Parra, Variation of the orchid bees community (Hymenoptera: Apidae) in three altered habitats of the Colombian "llano" piedmont. *Rev. Biol. Trop.* **55**, 931–941 (2007).
317. L. Parry, J. O. S. Barlow, C. A. Peres, Hunting for sustainability in tropical secondary forests. *Conserv. Biol.* **23**, 1270–1280 (2009).
318. N. Pelegrin, E. H. Bucher, Effects of habitat degradation on the lizard assemblage in the Arid Chaco, central Argentina. *J. Arid Environ.* **79**, 13–19 (2012).
319. C. A. Peres, H. S. Nascimento, Impact of game hunting by the Kayapo of south-eastern Amazonia: implications for wildlife conservation in tropical forest indigenous reserves. *Biodivers. Conserv.* **15**, 2627–2653 (2006).
320. R. S. Pethiyagoda Jr., K. Manamendra-Arachchi, Endangered anurans in a novel forest in the highlands of Sri Lanka. *Wildl. Res.* **39**, 641–648 (2012).
321. B. Phalan, M. Onial, A. Balmford, R. E. Green, Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science* **333**, 1289–1291 (2011).
322. J. Pincheira-Ulbrich, J. R. Rau, C. Smith-Ramirez, Vascular epiphytes and climbing plants diversity in an agroforestal landscape in southern Chile: a comparison among native forest fragments. *Bol. La Soc. Argentina Bot.* **47**, 411–426 (2012).
323. E. Pineda, G. Halffter, Species diversity and habitat fragmentation: frogs in a tropical montane landscape in Mexico. *Biol. Conserv.* **117**, 499–508 (2004).
324. S. L. Poggio, E. J. Chaneton, C. M. Ghersa, The arable plant diversity of intensively managed farmland: Effects of field position and crop type at local and landscape scales. *Agric. Ecosyst. Environ.* **166**, 55–64 (2013).
325. N. Politi, M. Hunter Jr., L. Rivera, Assessing the effects of selective logging on birds in Neotropical piedmont and cloud montane forests. *Biodivers. Conserv.* **21**, 3131–3155 (2012).
326. P. Pons, C. Wendenburg, The impact of fire and forest conversion into savanna on the bird communities of West Madagascan dry forests. *Anim. Conserv.* **8**, 183–193 (2005).
327. K. Poveda, E. Martinez, M. F. Kersch-Becker, M. A. Bonilla, T. Tscharntke, Landscape simplification and altitude affect biodiversity, herbivory and Andean potato yield. *J. Appl. Ecol.* **49**, 513–522 (2012).
328. E. F. Power, D. L. Kelly, J. C. Stout, Organic farming and landscape structure: effects on insect-pollinated plant diversity in intensively managed grasslands. *PLoS One* **7**, e38073 (2012), doi:10.1371/journal.pone.0038073.
329. E. F. Power, J. C. Stout, Organic dairy farming: impacts on insect-flower interaction networks and pollination. *J. Appl. Ecol.* **48**, 561–569 (2011).
330. S. J. Presley, M. R. Willig, J. M. W. Jr, L. N. Saldanha, Effects of reduced-impact logging and forest physiognomy on bat populations of lowland Amazonian forest. *J. Appl. Ecol.* **45**, 14–25 (2008).

331. V. M. Proença, H. M. Pereira, J. Guilherme, L. Vicente, Plant and bird diversity in natural forests and in native and exotic plantations in NW Portugal. *Acta Oecologica* **36**, 219–226 (2010).
332. M. Quaranta *et al.*, Wild bees in agroecosystems and semi-natural landscapes. 1997-2000 collection period in Italy. *Bull. Insectology* **57**, 11–62 (2004).
333. C. Quintero, C. L. Morales, M. A. Aizen, Effects of anthropogenic habitat disturbance on local pollinator diversity and species turnover across a precipitation gradient. *Biodivers. Conserv.* **19**, 257–274 (2010).
334. R. Rader, I. Bartomeus, J. M. Tylianakis, E. Laliberté, The winners and losers of land use intensification: pollinator community disassembly is non-random and alters functional diversity. *Divers. Distrib.* **20**, 908–917 (2014).
335. J. Ranganathan, K. M. A. Chan, G. C. Daily, Satellite detection of bird communities in tropical countryside. *Ecol. Appl.* **17**, 1499–1510 (2007).
336. J. Ranganathan, R. J. R. Daniels, M. D. S. Chandran, P. R. Ehrlich, G. C. Daily, Sustaining biodiversity in ancient tropical countryside. *Proc. Natl. Acad. Sci. U. S. A.* **105**, 17852–17854 (2008).
337. F. Raub, H. Hoefer, L. Scheuermann, R. Brandl, The conservation value of secondary forests in the southern Brazilian Mata Atlantica from a spider perspective. *J. Arachnol.* **42**, 52–73 (2014).
338. N. Redpath, L. M. Osgathorpe, K. Park, D. Goulson, Crofting and bumblebee conservation: The impact of land management practices on bumblebee populations in northwest Scotland. *Biol. Conserv.* **143**, 492–500 (2010).
339. J. L. Reid, J. B. C. Harris, R. A. Zahawi, Avian habitat preference in tropical forest restoration in southern Costa Rica. *Biotropica* **44**, 350–359 (2012).
340. Y. T. Reis, E. M. Cancello, Termite (Insecta, Isoptera) richness in primary and secondary Atlantic Forest in southeastern Bahia. *Iheringia Ser. Zool.* **97**, 229–234 (2007).
341. J. M. Rey-Benayas, I. Galvan, L. M. Carrascal, Differential effects of vegetation restoration in Mediterranean abandoned cropland by secondary succession and pine plantations on bird assemblages. *For. Ecol. Manage.* **260**, 87–95 (2010).
342. C. Reynolds, C. T. Symes, Grassland bird response to vegetation structural heterogeneity and clearing of invasive bramble. *African Zool.* **48**, 228–239 (2013).
343. D. B. Ribeiro, A. V. L. Freitas, The effect of reduced-impact logging on fruit-feeding butterflies in Central Amazon, Brazil. *J. Insect Conserv.* **16**, 733–744 (2012).
344. B. A. Richardson, M. J. Richardson, F. N. Soto-Adames, Separating the effects of forest type and elevation on the diversity of litter invertebrate communities in a humid tropical forest in Puerto Rico. *J. Anim. Ecol.* **74**, 926–936 (2005).
345. C. A. Robles, C. C. Carmaran, S. E. Lopez, Screening of xylophagous fungi associated with *Platanus acerifolia* in urban landscapes: Biodiversity and potential biodeterioration. *Landsc. Urban Plan.* **100**, 129–135 (2011).
346. M. M. Rodrigues, M. A. Uchoa, S. Ide, Dung beetles (Coleoptera: Scarabaeoidea) in three landscapes in Mato Grosso do Sul, Brazil. *Brazilian J. Biol.* **73**, 211–220 (2013).
347. J. Römbke, P. Schmidt, H. Höfer, The earthworm fauna of regenerating forests and anthropogenic habitats in the coastal region of Paraná. *Pesqui. Agropecu. Bras.* **44**, 1040–1049 (2009).

348. L. P. Romero-Duque, V. J. Jaramillo, A. Perez-Jimenez, Structure and diversity of secondary tropical dry forests in Mexico, differing in their prior land-use history. *For. Ecol. Manage.* **253**, 38–47 (2007).
349. L. Rosselli, thesis, *Factores ambientales relacionados con la presencia y abundancia de las aves de los humedales de la Sabana de Bogotá*. (Universidad Nacional de Colombia, 2011).
350. L. Rousseau, S. J. Fonte, O. Tellez, R. van der Hoek, P. Lavelle, Soil macrofauna as indicators of soil quality and land use impacts in smallholder agroecosystems of western Nicaragua. *Ecol. Indic.* **27**, 71–82 (2013).
351. A. V Rubio, J. A. Simonetti, Lizard assemblages in a fragmented landscape of central Chile. *Eur. J. Wildl. Res.* **57**, 195–199 (2011).
352. S. Safian, G. Csontos, D. Winkler, Butterfly community recovery in degraded rainforest habitats in the Upper Guinean Forest Zone (Kakum forest, Ghana). *J. Insect Conserv.* **15**, 351–359 (2011).
353. W. Sakchoowong, S. Nomura, K. Ogata, J. Chanpaisaeng, Diversity of pselaphine beetles (Coleoptera: Staphylinidae: Pselaphinae) in eastern Thailand. *Entomol. Sci.* **11**, 301–313 (2008).
354. R. A. Saldana-Vazquez, V. J. Sosa, J. R. Hernandez-Montero, F. Lopez-Barrera, Abundance responses of frugivorous bats (Stenodermatinae) to coffee cultivation and selective logging practices in mountainous central Veracruz, Mexico. *Biodivers. Conserv.* **19**, 2111–2124 (2010).
355. K. Sam, B. Koane, S. Jeppy, V. Novotny, Effect of forest fragmentation on bird species richness in Papua New Guinea. *J. F. Ornithol.* **85**, 152–167 (2014).
356. U. Samnegård, A. S. Persson, H. G. Smith, Gardens benefit bees and enhance pollination in intensively managed farmland. *Biol. Conserv.* **144**, 2602–2606 (2011).
357. J. Santana, M. Porto, L. Gordinho, L. Reino, P. Beja, Long-term responses of Mediterranean birds to forest fuel management. *J. Appl. Ecol.* **49**, 632–643 (2012).
358. J. Savage, T. A. Wheeler, A. M. A. Moores, A. G. Taillefer, Effects of habitat size, vegetation cover, and surrounding land use on Diptera diversity in temperate Nearctic bogs. *Wetlands* **31**, 125–134 (2011).
359. M. Schilthuizen, T. S. Liew, B. Bin Elahan, I. Lackman-Ancrenaz, Effects of karst forest degradation on pulmonate and prosobranch land snail communities in Sabah, Malaysian Borneo. *Conserv. Biol.* **19**, 949–954 (2005).
360. N. L. Schon, A. D. Mackay, M. A. Minor, G. W. Yeates, M. J. Hedley, Soil fauna in grazed New Zealand hill country pastures at two management intensities. *Appl. Soil Ecol.* **40**, 218–228 (2008).
361. N. L. Schon, A. D. Mackay, G. W. Yeates, M. A. Minor, Separating the effects of defoliation and dairy cow treading pressure on the abundance and diversity of soil invertebrates in pastures. *Appl. Soil Ecol.* **46**, 209–221 (2010).
362. C. Schüepp, J. D. Herrmann, F. Herzog, M. H. Schmidt-Entling, Differential effects of habitat isolation and landscape composition on wasps, bees, and their enemies. *Oecologia* **165**, 713–721 (2011).
363. C. Schüepp, S. Rittiner, M. H. Entling, High bee and wasp diversity in a heterogeneous tropical farming system compared to protected forest. *PLoS One* **7**, e52109 (2012).

364. K. Schumann, R. Wittig, A. Thiombiano, U. Becker, K. Hahn, Impact of land-use type and harvesting on population structure of a non-timber forest product-providing tree in a semi-arid savanna, West Africa. *Biol. Conserv.* **144**, 2369–2376 (2011).
365. D. M. Scott *et al.*, The impacts of forest clearance on lizard, small mammal and bird communities in the arid spiny forest, southern Madagascar. *Biol. Conserv.* **127**, 72–87 (2006).
366. K. A. Scott, S. A. Setterfield, M. M. Douglas, A. N. Andersen, Fire tolerance of perennial grass tussocks in a savanna woodland. *Austral Ecol.* **35**, 858–861 (2010).
367. J. L. Sedlock *et al.*, Bat diversity in tropical forest and agro-pastoral habitats within a protected area in the Philippines. *Acta Chiropterologica* **10**, 349–358 (2008).
368. N. J. Shafie, S. A. M. Sah, N. S. A. Latip, N. M. Azman, N. L. Khairuddin, Diversity pattern of bats at two contrasting habitat types along Kerian River, Perak, Malaysia. *Trop. Life Sci. Res.* **22**, 13–22 (2011).
369. G. Shahabuddin, R. Kumar, Effects of extractive disturbance on bird assemblages, vegetation structure and floristics in tropical scrub forest, Sariska Tiger Reserve, India. *For. Ecol. Manage.* **246**, 175–185 (2007).
370. G. Shannon *et al.*, The utilization of large savanna trees by elephant in southern Kruger National Park. *J. Trop. Ecol.* **24**, 281–289 (2008).
371. D. Sheil *et al.*, *Exploring biological diversity, environment and local people's perspectives in forest landscapes: Methods for a multidisciplinary landscape assessment*. (Center for International Forestry Research, Jakarta, Indonesia, 2002).
372. F. H. Sheldon, A. Styring, P. A. Hosner, Bird species richness in a Bornean exotic tree plantation: A long-term perspective. *Biol. Conserv.* **143**, 399–407 (2010).
373. R. E. Shuler, T. H. Roulston, G. E. Farris, Farming practices influence wild pollinator populations on squash and pumpkin. *J. Econ. Entomol.* **98**, 790–795 (2005).
374. S. J. Siebert, Patterns of plant species richness of temperate and tropical grassland in South Africa. *Plant Ecol. Evol.* **144**, 249–254 (2011).
375. F. A. B. Silva, C. M. Q. Costa, R. C. Moura, A. I. Farias, Study of the dung beetle (Coleoptera: Scarabaeidae) community at two sites: Atlantic Forest and clear-cut, Pernambuco, Brazil. *Environ. Entomol.* **39**, 359–367 (2010).
376. E. M. Slade, D. J. Mann, O. T. Lewis, Biodiversity and ecosystem function of tropical forest dung beetles under contrasting logging regimes. *Biol. Conserv.* **144**, 166–174 (2011).
377. A. Smith-Pardo, V. H. Gonzalez, Diversidad de abejas (Hymenoptera: Apoidea) en estados sucesionales del bosque humedo tropical. *Acta Biológica Colomb.* **12**, 43–55 (2007).
378. N. S. Sodhi *et al.*, Deforestation and avian extinction on tropical landbridge islands. *Conserv. Biol.* **24**, 1290–1298 (2010).
379. M. C. K. Soh, N. S. Sodhi, S. L. H. Lim, High sensitivity of montane bird communities to habitat disturbance in Peninsular Malaysia. *Biol. Conserv.* **129**, 149–166 (2006).
380. R. A. Sosa, V. A. Benz, J. M. Galea, I. V Poggio Herrero, Efecto del grado de disturbio sobre el ensamble de aves en la reserva provincial Parque Luro, La Pampa, Argentina. *Rev. la Asoc. Argentina Ecol. Paisajes*. **1**, 101–110 (2010).
381. H. Sridhar, T. R. S. Raman, D. Mudappa, Mammal persistence and abundance in tropical rainforest remnants in the southern Western Ghats, India. *Curr. Sci.* **94**, 748–757 (2008).
382. P. C. Stouffer, E. I. Johnson, R. O. Bierregaard Jr., T. E. Lovejoy, Understory bird communities in Amazonian rainforest fragments: species turnover through 25 years post-

isolation in recovering landscapes. *PLoS One* **6**, e20543 (2011), doi:10.1371/journal.pone.0020543.

383. L. Ström, K. Hylander, M. Dynesius, Different long-term and short-term responses of land snails to clear-cutting of boreal stream-side forests. *Biol. Conserv.* **142**, 1580–1587 (2009).

384. M. J. Struebig, T. Kingston, A. Zubaid, A. Mohd-Adnan, S. J. Rossiter, Conservation value of forest fragments to Palaeotropical bats. *Biol. Conserv.* **141**, 2112–2126 (2008).

385. Z. M. Su, R. Z. Zhang, J. X. Qiu, Decline in the diversity of willow trunk-dwelling weevils (Coleoptera: Curculionoidea) as a result of urban expansion in Beijing, China. *J. Insect Conserv.* **15**, 367–377 (2011).

386. M. Suarez-Rubio, J. R. Thomlinson, Landscape and patch-level factors influence bird communities in an urbanized tropical island. *Biol. Conserv.* **142**, 1311–1321 (2009).

387. S. Sugiura, T. Tsuru, Y. Yamaura, H. Makihara, Small off-shore islands can serve as important refuges for endemic beetle conservation. *J. Insect Conserv.* **13**, 377–385 (2009).

388. K. S. Summerville, Managing the forest for more than the trees: effects of experimental timber harvest on forest Lepidoptera. *Ecol. Appl.* **21**, 806–816 (2011).

389. K. S. Summerville, C. J. Conoan, R. M. Steichen, Species traits as predictors of lepidopteran composition in restored and remnant tallgrass prairies. *Ecol. Appl.* **16**, 891–900 (2006).

390. K. S. Summerville, T. O. Crist, Effects of timber harvest on forest Lepidoptera: community, guild and species responses. *Ecol. Appl.* **12**, 820–835 (2002).

391. Y. H. Sung, N. E. Karraker, B. C. H. Hau, Terrestrial herpetofaunal assemblages in secondary forests and exotic *Lophostemon confertus* plantations in South China. *For. Ecol. Manage.* **270**, 71–77 (2012).

392. C. G. Threlfall, B. Law, P. B. Banks, Sensitivity of insectivorous bats to urbanization: Implications for suburban conservation planning. *Biol. Conserv.* **146**, 41–52 (2012).

393. R. Tonietto, J. Fant, J. Ascher, K. Ellis, D. Larkin, A comparison of bee communities of Chicago green roofs, parks and prairies. *Landsc. Urban Plan.* **103**, 102–108 (2011).

394. I. Torre, V. Bros, X. Santos, Assessing the impact of reforestation on the diversity of Mediterranean terrestrial Gastropoda. *Biodivers. Conserv.* **23**, 2579–2589 (2014).

395. E. C. Turner, W. A. Foster, The impact of forest conversion to oil palm on arthropod abundance and biomass in Sabah, Malaysia. *J. Trop. Ecol.* **25**, 23–30 (2009).

396. J. M. Tylianakis, A.-M. Klein, T. Tscharntke, Spatiotemporal variation in the diversity of Hymenoptera across a tropical habitat gradient. *Ecology* **86**, 3296–3302 (2005).

397. M. Uehara-Prado, Effects of land use on ant species composition and diaspore removal in exotic grasslands in the Brazilian Pantanal (Hymenoptera: Formicidae). *Sociobiology* **45**, 915–923 (2005).

398. M. Uehara-Prado, K. S. Brown, A. Victor, L. Freitas, Species richness, composition and abundance of fruit-feeding butterflies in the Brazilian Atlantic Forest: comparison between a fragmented and a continuous landscape. *Glob. Ecol. Biogeogr.* **16**, 43–54 (2007).

399. J. N. Urbina-Cardona, M. Olivares-Perez, V. H. Reynoso, Herpetofauna diversity and microenvironment correlates across a pasture-edge-interior ecotone in tropical rainforest fragments in the Los Tuxtlas Biosphere Reserve of Veracruz, Mexico. *Biol. Conserv.* **132**, 61–75 (2006).

400. J. N. Urbina-Cardona, M. C. Londoño-Murcia, D. G. García-Ávila, Spatio-temporal dymanics of snake diversity in four habitats with different degrees of anthropogenic

disturbance in the Gorgona Island National Natural Park in the Colombian Pacific. *Caldasia* **30**, 479–493 (2008).
401. D. Vallan, Effects of anthropogenic environmental changes on amphibian diversity in the rain forests of eastern Madagascar. *J. Trop. Ecol.* **18**, 725–742 (2002).
402. A. J. Vanbergen, B. A. Woodcock, A. D. Watt, J. Niemela, Effect of land-use heterogeneity on carabid communities at the landscape scale. *Ecography* **28**, 3–16 (2005).
403. H. L. Vasconcelos *et al.*, Dynamics of the leaf-litter arthropod fauna following fire in a Neotropical woodland savanna. *PLoS One* **4**, e7762 (2009).
404. K. Vassilev, H. Pedashenko, S. C. Nikolov, I. Apostolova, J. Dengler, Effect of land abandonment on the vegetation of upland semi-natural grasslands in the Western Balkan Mts., Bulgaria. *Plant Biosyst.* **145**, 654–665 (2011).
405. D. P. Vázquez, D. Simberloff, Ecological specialization and susceptibility to disturbance: Conjectures and refutations. *Am. Nat.* **159**, 606–623 (2002).
406. H. A. F. Verboven, R. Brys, M. Hermy, Sex in the city: Reproductive success of *Digitalis purpurea* in a gradient from urban to rural sites. *Landsc. Urban Plan.* **106**, 158–164 (2012).
407. M. J. Verdasca *et al.*, Forest fuel management as a conservation tool for early successional species under agricultural abandonment: The case of Mediterranean butterflies. *Biol. Conserv.* **146**, 14–23 (2012).
408. J. R. Verdú *et al.*, Grazing promotes dung beetle diversity in the xeric landscape of a Mexican Biosphere Reserve. *Biol. Conserv.* **140**, 308–317 (2007).
409. C. H. Vergara, E. I. Badano, Pollinator diversity increases fruit production in Mexican coffee plantations: The importance of rustic management systems. *Agric. Ecosyst. Environ.* **129**, 117–123 (2009).
410. P. M. Vergara, J. A. Simonetti, Avian responses to fragmentation of the Maulino Forest in central Chile. *Oryx* **38**, 383–388 (2004).
411. M. Virgilio, T. Backeljau, R. Emeleme, J. L. Juakali, M. De Meyer, A quantitative comparison of frugivorous tephritids (Diptera: Tephritidae) in tropical forests and rural areas of the Democratic Republic of Congo. *Bull. Entomol. Res.* **101**, 591–597 (2011).
412. L. Van Vu, C. Q. Vu, Diversity pattern of butterfly communities (Lepidoptera, Papilionoidae) in different habitat types in a tropical rain forest of Southern Vietnam. *ISRN Zool.* **2011**, 1–8 (2011).
413. E. M. Waite, G. Closs, Y. Van Heezik, C. Berry, K. Dickinson, Arboreal arthropod sampling methods for urban trees. *J. Insect Conserv.* **16**, 931–939 (2012).
414. E. Waite, G. P. Closs, Y. van Heezik, K. J. M. Dickinson, Resource availability and foraging of silvereyes (*Zosterops lateralis*) in urban trees. *Emu* **113**, 26–32 (2013).
415. S. Walker, D. J. Wilson, G. Norbury, A. Monks, A. J. Tanentzap, Complementarity of indigenous flora in shrublands and grasslands in a New Zealand dryland landscape. *N. Z. J. Ecol.* **38**, 230–241 (2014).
416. T. R. Walker, P. D. Crittenden, S. D. Young, T. Prystina, An assessment of pollution impacts due to the oil and gas industries in the Pechora Basin, north-eastern European Russia. *Ecol. Indic.* **6**, 369–387 (2006).
417. Y. Wang, Y. Bao, M. Yu, G. Xu, P. Ding, Nestedness for different reasons: the distributions of birds, lizards and small mammals on islands of an inundated lake. *Divers. Distrib.* **16**, 862–873 (2010).
418. J. I. Watling, K. Gerow, M. A. Donnelly, Nested species subsets of amphibians and reptiles on Neotropical forest islands. *Anim. Conserv.* **12**, 467–476 (2009).

419. B. Weller, J. U. Ganzhorn, Carabid beetle community composition, body size, and fluctuating asymmetry along an urban-rural gradient. *Basic Appl. Ecol.* **5**, 193–201 (2004).
420. K. Wells, E. K. V. Kalko, M. B. Lakim, M. Pfeiffer, Effects of rain forest logging on species richness and assemblage composition of small mammals in Southeast Asia. *J. Biogeogr*. **34**, 1087–1099 (2007).
421. E. D. Wiafe, R. Amfo-Otu, Forest duiker (*Cephalophus* spp.) abundance and hunting activities in the Kakum conservation area, Ghana. *J. Ecol. Nat. Environ.* **4**, 114–118 (2012).
422. C. D. Williams, J. Sheahan, M. J. Gormally, Hydrology and management of turloughs (temporary lakes) affect marsh fly (Sciomyzidae: Diptera) communities. *Insect Conserv. Divers.* **2**, 270–283 (2009).
423. M. R. Willig *et al.*, Phyllostomid bats of lowland Amazonia: effects of habitat alteration on abundance. *Biotropica* **39**, 737–746 (2007).
424. R. Winfree, T. Griswold, C. Kremen, Effect of human disturbance on bee communities in a forested ecosystem. *Conserv. Biol.* **21**, 213–223 (2007).
425. J. C. Z. Woinarski *et al.*, Fauna assemblages in regrowth vegetation in tropical open forests of the Northern Territory, Australia. *Wildl. Res.* **36**, 675–690 (2009).
426. B. A. Woodcock *et al.*, The potential of grass field margin management for enhancing beetle diversity in intensive livestock farms. *J. Appl. Ecol.* **44**, 60–69 (2007).
427. T. Wronski *et al.*, Species richness and meta-community structure of land snails along an altitudinal gradient on Bioko Island, Equatorial Guinea. *J. Molluscan Stud.* **80**, 161–168 (2014).
428. J. M. Wunderle, L. M. P. Henriques, M. R. Willig, Short-term responses of birds to forest gaps and understory: an assessment of reduced-impact logging in a lowland Amazon Forest. *Biotropica* **38**, 235–255 (2006).
429. Y. Yamaura *et al.*, Biodiversity of man-made open habitats in an underused country: a class of multispecies abundance models for count data. *Biodivers. Conserv.* **21**, 1365–1380 (2012).
430. X. L. Yan, W. K. Bao, X. Y. Pang, N. X. Zhang, J. Q. Chen, Regeneration strategies influence ground bryophyte composition and diversity after forest clearcutting. *Ann. For. Sci.* **70**, 845–861 (2013).
431. X. Yan, W. Bao, Evaluation of species composition and development of bryophyte community during early natural recovery progress of high-altitude spruce cutovers. *Biodivers. Sci.* **16**, 110–117 (2008).
432. X.-L. Yan, W.-K. Bao, Structure and species composition of ground bryophyte community of high-altitude young silvicultural cutovers in Rangtang County, China: evaluation on effects of clear-cutting and silvicultural management. *Chinese J. Plant Ecol.* **32**, 815–824 (2008).
433. S. Yoshikura, S. Yasui, T. Kamijo, Comparative study of forest-dwelling bats' abundances and species richness between old-growth forests and conifer plantations in Nikko National Park, central Japan. *Mamm. Stud.* **36**, 189–198 (2011).
434. A. S. Zaitsev, M. Chauvat, A. Pflug, V. Wolters, Oribatid mite diversity and community dynamics in a spruce chronosequence. *Soil Biol. Biochem.* **34**, 1919–1927 (2002).
435. A. S. Zaitsev, V. Wolters, R. Waldhardt, J. Dauber, Long-term succession of oribatid mites after conversion of croplands to grasslands. *Appl. Soil Ecol.* **34**, 230–239 (2006).
436. J. N. Zhang, Q. Li, W. J. Liang, Effect of acetochlor and carbofuran on soil nematode communities in a Chinese soybean field. *African J. Agric. Res.* **5**, 2787–2794 (2010).

437. G. Zimmerman, F. W. Bell, J. Woodcock, A. Palmer, J. Paloniemi, Response of breeding songbirds to vegetation management in conifer plantations established in boreal mixedwoods. *For. Chron.* **87**, 217–224 (2011).
438. P. A. Murtaugh, Performance of several variable-selection methods applied to real ecological data. *Ecol. Lett.* **12**, 1061–1068 (2009).
439. D. Bates, M. Maechler, B. Bolker, S. Walker, *lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1-7* (2014; http://cran.r-project.org/package=lme4).
440. R Core Team, *R: A Language and Environment for Statistical Computing* (2015; https://www.r-project.org/).
441. G. C. Hurtt et al., *Clim. Change* **109**, 117–161 (2011).
442. Q. Mu, M. Zhao, S. W. Running, Improvements to a MODIS global terrestrial evapotranspiration algorithm. *Remote Sens. Environ.* **115**, 1781–1800 (2011).
443. R. J. Hijmans, S. E. Cameron, J. L. Parra, P. G. Jones, A. Jarvis, Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* **25**, 1965–1978 (2005).
444. H. I. Reuter, T. Hengl, in *Digital Soil Assessments and Beyond*, B. Minasny, B. P. Malone, A. B. McBratney, Eds. (Taylor & Francis Group, Sydney, Australia, 2012).
445. T. Hengl *et al.*, SoilGrids1km — global soil information based on automated mapping. *PLoS One* **9**, e105992 (2014).
446. A. Nelson, *Estimated travel time to the nearest city of 50,000 or more people in year 2000*. (Ispra, Italy, 2008; http://bioval.jrc.ec.europa.eu/products/gam/).
447. M.-N. Tuanmu, W. Jetz, A global 1-km consensus land-cover product for biodiversity and ecosystem modelling. *Glob. Ecol. Biogeogr.* **23**, 1031–1045 (2014).
448. B. Lehner, P. Döll, Development and validation of a global database of lakes, reservoirs and wetlands. *J. Hydrol.* **296**, 1–22 (2004).
449. D. M. Olson *et al.*, Terrestrial ecoregions of the world: a new map of life on Earth. *Bioscience*. **51**, 933–938 (2001).
450. 450. S. van Asselen, P. H. Verburg, Land cover change or land-use intensification: simulating land system change with a global-scale land change model. *Glob. Chang. Biol.* **19**, 3648–67 (2013).
451. ESRI, ArcGIS Desktop: Release 10. (2011).
452. A. Longacre, L. R. Scott, J. S. Levine, Linear independence of pairwise comparisons of DNA microarray data. *J. Bioinform. Comput. Biol.* **3**, 1243–1262 (2005).
453. A. Chao, R. L. Chazdon, R. K. Colwell, T.-J. Shen, A new statistical approach for assessing similarity of species composition with incidence and abundance data. *Ecol. Lett.* **8**, 148–159 (2005).
454. R. A. Mittermeier *et al.*, Wilderness and biodiversity conservation. *Proc. Natl. Acad. Sci. U. S. A.* **100**, 10309–10313 (2003).
455. A. D. Chapman, *Numbers of Living Species in Australia and the World* (Australian Biological Resources Study, Canberra, Australia, 2009; https://www.environment.gov.au/system/files/pages/2ee3f4a1-f130-465b-9c7a-79373680a067/files/nlsaw-2nd-complete.pdf).
456. J. C. Pinheiro, D. M. Bates, *Mixed-effects models in S and S-plus* (Springer, New York, U.S.A., 2000).
457. A. F. Zuur, E. N. Ieno, N. J. Walker, A. A. Saveliev, G. M. Smith, *Mixed Effects Models and Extensions in Ecology with R* (Springer, New York, U.S.A., 2009).

Acknowledgments: We thank the hundreds of researchers who contributed their data to the PREDICTS project; and Georgina Mace and Neil Burgess for helpful comments on an earlier draft. This work was funded by the UK Natural Environment Research Council (NERC, grant numbers: NE/J011193/2 and NE/L002515/1), the Biotechnology and Biological Sciences Research Council (grant number: BB/F017324/1), a Hans Rausing PhD scholarship, and the United Nations Environment Programme World Conservation Monitoring Centre. This is a contribution from the Imperial College Grand Challenges in Ecosystem and the Environment Initiative, and the Sussex Sustainability Research Programme. PREDICTS is endorsed by the Group on Earth Observations Biodiversity Observation Network (GEO-BON). The underlying biodiversity data can be downloaded from the Natural History Museum's Data Portal (doi: http://dx.doi.org/10.5519/0073893).

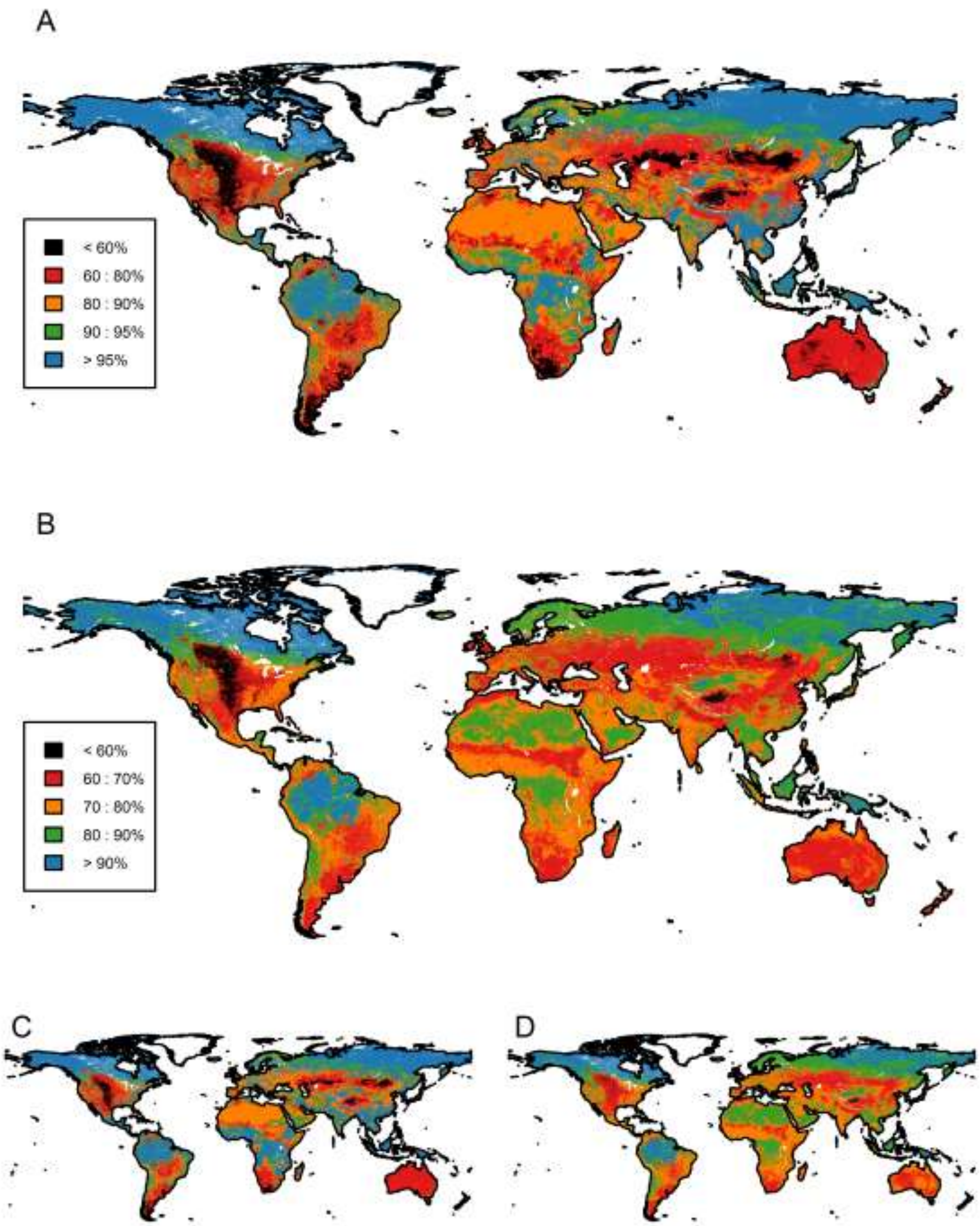

Fig. 1. **Biodiversity intactness of ecological assemblages,** in terms of (**A**) total abundance of species occurring in primary vegetation (i.e. BII), (**B**) richness of species occurring in primary vegetation. Panels **C** and **D** correspond to A and B, respectively, and have the same legend values, but including species not present in primary vegetation.

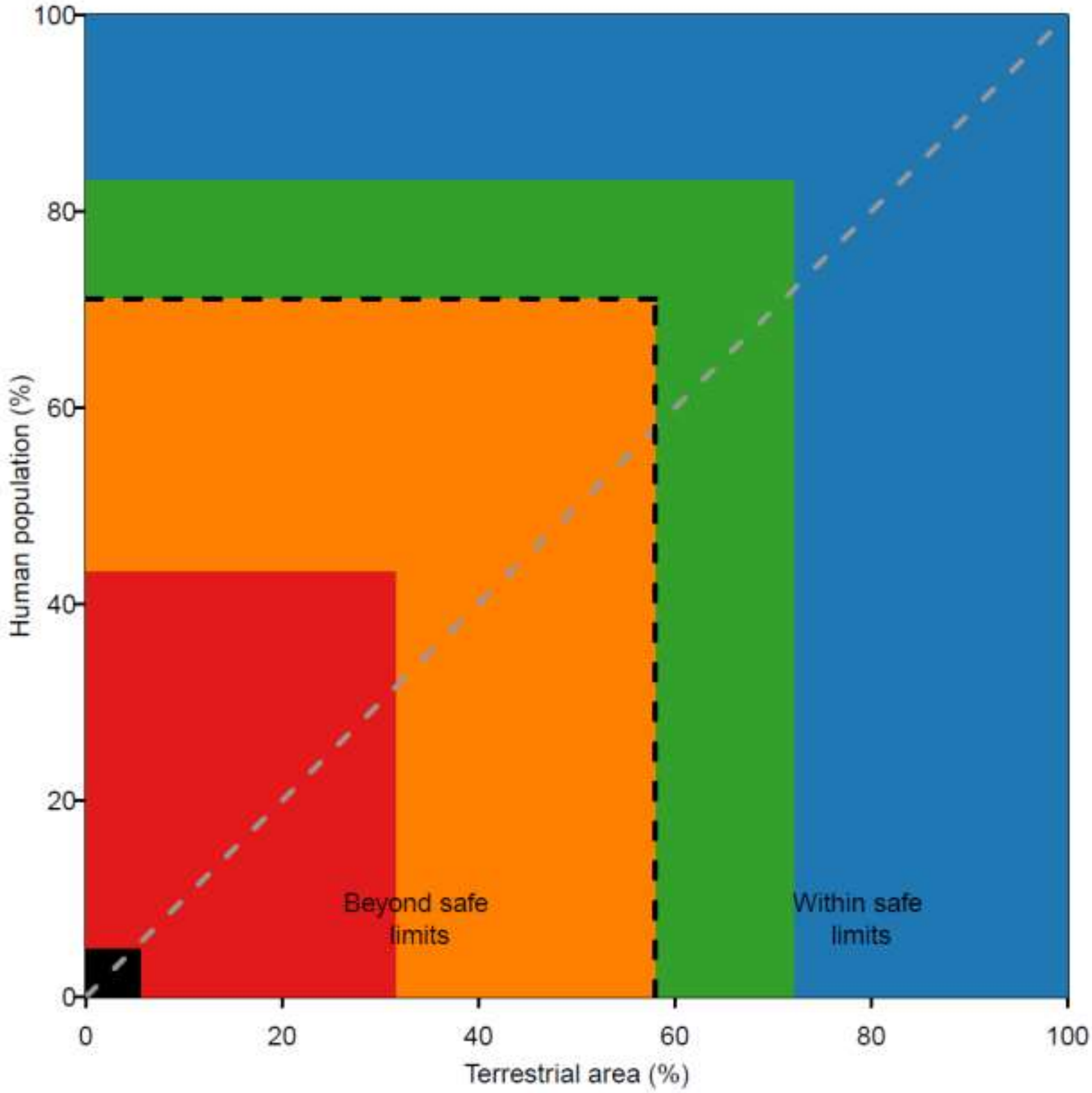

Fig. 2. Terrestrial area and human population at different levels of the Biodiversity Intactness Index (BII). Biodiversity intactness increases from bottom-left to top-right, and has the same colour scheme as Fig. 1. The dashed black line shows the position of the planetary boundary *(9)*: only areas to the right and human population above this line (shaded green and blue) are within the proposed safe operating space. If human population were distributed randomly with respect to BII, the corners of the boxes would align with the dashed grey line; the extent to which the corners lie above this line indicates the strength of the bias in human populations toward less intact areas.

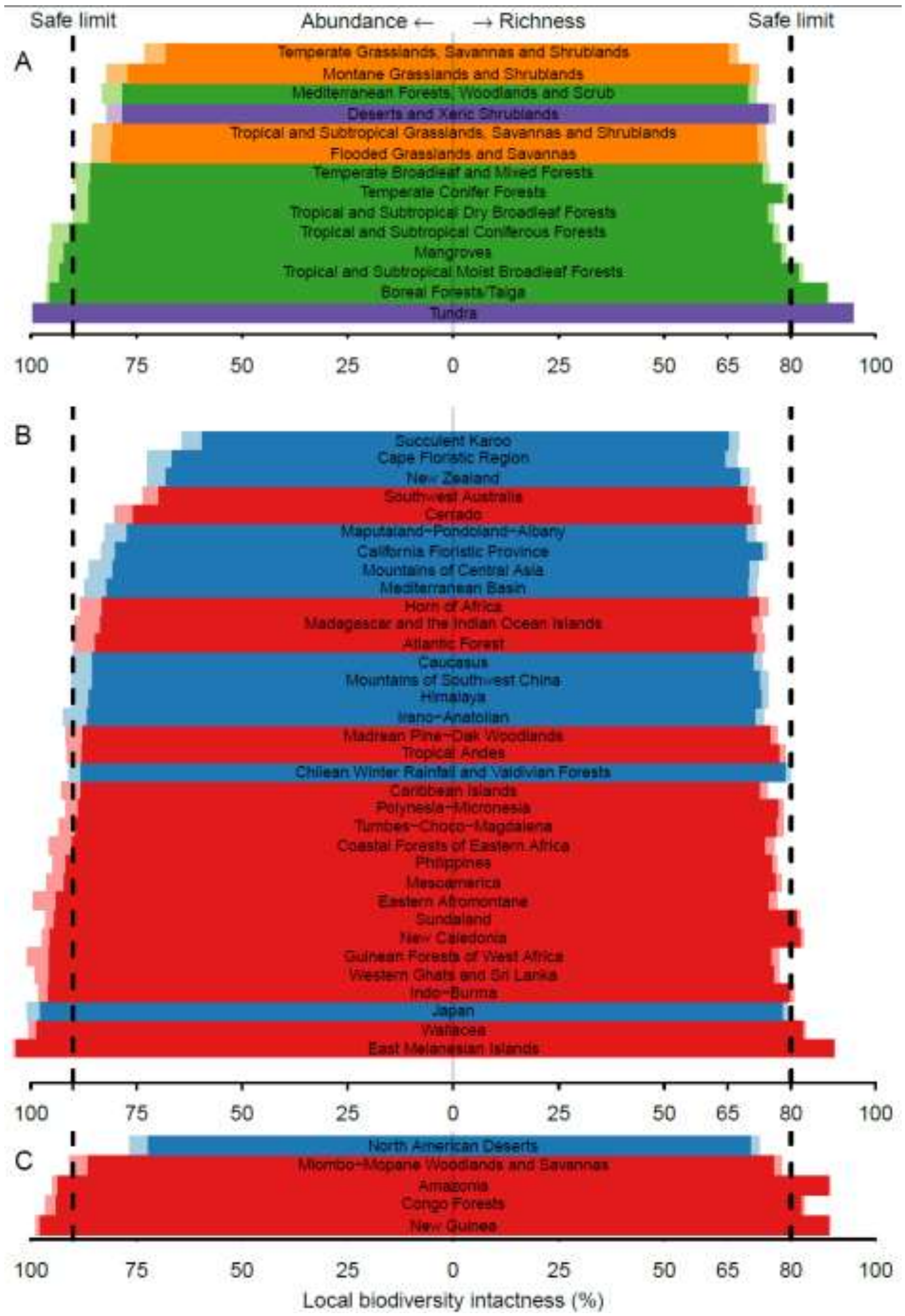

Fig. 3. Biodiversity intactness for biomes, Biodiversity Hotspots and High Biodiversity Wilderness Areas. Biodiversity intactness in terms of total abundance (BII; solid bars on left) and species richness (solid bars on right) in each of 14 terrestrial biomes (**A**), 34 Biodiversity Hotspots (**B**), and five High Biodiversity Wilderness Areas (**C**). Translucent bars show the corresponding relative biodiversity values if novel species are treated as equivalent to those originally present (these numbers can surpass 100% because gains may outnumber losses). Bars in (A) are coloured by major biome type (orange = grasslands, green = forests, purple = other), while bars in (B) and (C) are coloured according to whether they are in the temperate (blue) or tropical (red) realms.

Supplementary Materials:

Materials and Methods

Figures S1-S7

Tables S1-S7

References (*31*-*457*)