

Supporting Information

INTRODUCTION

Table S1.

Title: Motivations and opportunistic forces.

Legend: Motivations and opportunistic forces related to the implementation of protected areas, sorted by appearance in history. Acronym: protected areas, PA.

#	Group	Name	Origin	Description	PA expected location	PA examples
1	Preferential motivations	Cultural and spiritual	Anthropocentric and non-utilitarian.	Protection is biased towards remarkable natural and/or cultural sceneries, as their aesthetic appreciation –through direct contact– ensures the fulfillment of basic human needs and thus the well-being of individuals and societies (Badshah & Bhadran 1962; Bhagwat & Rutte 2006; Loreau 2014)	Near to populated areas	Forêt de Fontainebleau (France, 1861), Uluṛu-Kata Tjuṛa National Park (Australia, 1958)
2			Early formation of unified societies (e.g. feudal)			
		Gaming and wildlife managing	Anthropocentric and utilitarian.	Land is set aside to limit hunting wildlife with the aim of maintaining healthy animal populations (specially ‘singular’ species) and –in the case of gaming– providing recreation to a restricted part of society	In high animal density areas	Białowieża Forest (Poland/Belarus, <1541), Pongola Game Reserve (South Africa, 1894)
3		National imaginary	Anthropocentric and non-utilitarian.	Similar to #1, but with a planned governmental aim of shaping a national pride and identity through natural or cultural icons	Random	Iguazú/Iguaçu National Parks (Argentina/Brazil, 1935/1939)
			Consolidation of modern states			
4	Frontier protection and peace preservation	Frontier protection and peace preservation	Anthropocentric and utilitarian.	International borders can be conceived as areas where assert sovereignty or as neutral zones fostering or dedicated to cooperative and peaceful economical activities (Zbicz & Green 1997)	Adjacent or close to international borders	Waterton-Glacier International Peace Park (Canada/USA, 1932)
			Post-independence			
5	Ecosystem goods and services	Ecosystem goods and services	Anthropocentric and utilitarian.	Protection is closely related to healthy and functionally stable ecosystems, able to supply over time critical environmental goods and services (timber, water, pollination, soil	Variable, according to the good or service	Malleco National Reserve (Chile, 1907)
			Early, but the			

		provision	service concept was promoted since 1900.	protection, carbon sequestration) (Costanza et al. 1997)		
6		Tourism, leisure and recreation	Anthropocentric and utilitarian. Beginning of the 20 th century	Similar to #1, but with the aim of providing popular entertainment and enjoyment and bringing significant economic benefits to local to regional economies (Eagles et al. 2002; McKercher 1996; Mulholland & Eagles 2002)	In areas of high scenic or cultural value	Abel Tasman National Park (New Zealand, 1942), Nikkō National Park (Japan, 1934)
7		Biological conservation	Biocentric and non-utilitarian. Beginning of the 20 th century, but actively after 1960	Protection is based on the identification of biodiversity priorities in terms of species richness, rates of endemism, or unique species assemblies. The hotspot concept adds to previous items the risk of vegetation transformation (Myers et al. 2000; Parrish et al. 2003; Terborgh & Winter 1983)	In areas of high species richness	Virunga National Park (Congo DR, 1925), Komodo National Park (Indonesia, 1980)
8	Representative motivations	Abundance-based	Idem #7	Protection is focused on the representation of ecosystems (biota and processes) due to their intrinsic values (Kareiva & Marvier 2003; Margules & Pressey 2000; Pressey 1994), or as pristine scenarios where knowledge of the Earth system can be improved (Bourlière 1962). Assuming that ecosystem diversity is reflected in the diversity of biophysical conditions (Belbin 1993; Hoekstra et al. 2005; Holdridge 1947; Schimper et al. 1903; Woodward et al. 2004), individual areas or networks should sample at a similar rate biophysical conditions within a territory, achieving a targeted fraction of their area (McNeely et al. 1994; SCBD 2010)	Copying the relative abundance of biophysical conditions	
9		Quota-based	Idem #7	Idem #8, but individual areas or networks should evenly incorporate the diversity of biophysical conditions within a territory, achieving a similar targeted area	Equal area along biophysical gradients	
10	Opportunistic forces		Anthropocentric. Beginning of the 20 th century	Protection is set where opportunity exists, mostly where it is economically feasible, i.e. territories that have a low economic value for profitable land use (Margules & Pressey 2000)	In remote, isolated, lowly populated, or unsuitability for agriculture areas	Northeast Greenland National Park (Denmark, 1974)

METHODS

Data sources and sampling

11

12 Table S2.

13 Title: Variables related to motivations and opportunistic forces.

14 Legend: List of 15 biophysical, human, and biological independent variables, and their
 15 relation to the motivations and opportunistic forces of Table S1.

	Variable	Units	Calculation and source	Summarizing method	Group and name
1	Temperature	°C	Mean annual values, from the “Ten Minute Climatology data base” (New et al. 2002), representing averaged monthly figures for the 1961-1990 period	Mean	Representative motivations
2	Precipitation	Mm	Amount of annual precipitation. Same source as temperature		
3	Precipitation to potential evapotranspiration ratio (PPT:PET)	-	Mean annual values describing water availability. Same source as temperature. Potential evapotranspiration is retrieved from the Penman-Monteith equation (Allen et al. 2004) and calculated on a monthly bases		
4	Elevation	M (above sea level)	From “Shuttle Radar Topography Mission” (SRTM) digital elevation model (USGS 2004). Spatial resolution: 90 m		
5	Terrain slope	° (degrees)	From “Shuttle Radar Topography Mission” (SRTM) digital elevation model (USGS 2004).		
6	Soil fertility	cmolc * kg ⁻¹	Represented by top-soil total exchangeable bases (TEB, 0-30 cm). From ISRIC-WISE - Global data set of derived soil properties (v.3.0) (Batjes 2006). Spatial resolution: 30 arc-min		
7	Tourist attraction	photos * inhabitants ⁻¹	“Panoramio” photos (www.panoramio.com) to population counts ratio. Modified from the “World touristiness map” (www.blumoon.ee). Panoramio photos were downloaded in December 2013 and processed with Python v.2.7. Population came from the same source referred previously.		Preferential motivations: <i>Cultural and spiritual; National imaginary; Tourism, leisure and recreation</i>
8	Distance to frontiers	km	Considering exclusively cells within countries with terrestrial political frontiers. Euclidean distance from vector data from “Natural Earth”		Preferential motivations: <i>Frontier protection and peace</i>

			(www.naturalearthdata.com). Cartographic scale: 1:50 m		<i>preservation</i>
9	Biomass	Mg ha ⁻¹	Biomass carbon stored in above and belowground living vegetation circa 2000 (Ruesch & Gibbs 2008). Spatial resolution: 1 km	Maximum, representing attainable conditions	Preferential motivations: <i>Ecosystem goods and services provision</i>
10	Animal richness	sp	Number of breeding bird, amphibian, and mammal species from Jenkins et al. (2013). Spatial resolution: 10 km	Mean	Preferential motivations: <i>Biological conservation</i>
11	Vascular plant richness	sp	Number of vascular plant species from Kreft and Jetz (2007) (combined multipredictor model). Spatial resolution: 110 km		
12	Population	inh	Inhabitants from the “Gridded Population of the World v.3 (GPWv3): Population Grids” for the years 1990-1995 (CIESIN-CIAT 2005). Spatial resolution: 2.5 arc-min	Sum	Opportunistic forces
13	Isolation	min	From the 2000 map “Travel Time to Major Cities” (Nelson 2008). Representing the distance to large cities (>50,000 inh) by using a cost-distance algorithm. Spatial resolution: 0.5 arc-min	Minimum, representing human context of the surrounds of protected areas	
14	Distance to coasts	to km	Considering ocean coasts. Potentially related to the proximity to docking ports. Euclidean distance from vector data from “Natural Earth”.	Mean	
15	Cropland suitability	-	Land suitability for low input level rain-fed crops, considering cereals, soybean, and oil palm (FAO/IIASA 2011). Calculated as the maximum suitability of the included species, per pixel. Spatial resolution: 5 arc-min		

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17 Table S3.

18 Title: Samples by region and globe.

19 Legend: Number of 0.5° square cells samples, by region and globe.

Region	Samples
Latin America & Caribbean	7,607
North America & Australia–NZ	18,602
Sub-Saharan Africa	8,430
Middle East & North Africa	4,725
West Europe	3,462
East Europe & Central Asia	15,337
South-east Asia & Oceania	8,392
Global	66,555

21 **Data analysis**

22 In the process of understanding the behavior of the fraction under protection
 23 along the gradients of human and biological variables (related to preferential
 24 motivations and opportunistic forces), we assessed first and second order polynomials,
 25 exponentials, one phase associations, semi-logarithmic (X axis logarithmic, Y linear),
 26 and piecewise models (Faraway 2006). We selected models through the Akaike's
 27 information criterion (Akaike 1974), and calculated a pseudo- R^2 by correlating
 28 observed and predicted values from each model as a goodness-of-fit measurement. We
 29 considered the land area of each sample (i.e. cell) as a weighting factor. For all tests, we
 30 carried out the modeling with the values of ≥ 8 histogram intervals (if not, we divided
 31 classes up to accomplish this rule).

32 In relation to the random forest¹ (Grömping 2009; Liaw & Wiener 2002), the
 33 algorithm estimates the VI by looking at how much the mean square error (MSE)
 34 increases when the out-of-bag data (observations which are not used for building the
 35 current tree, OOB) for that variable is permuted while all others are left unchanged
 36 (Liaw & Wiener 2002). For each unpruned (fully grown) tree, the MSE on the OOB
 37 portion of the data is recorded, and then the same is done after permuting each
 38 independent variable. The difference between the two are then averaged over all trees,
 39 and normalized by the standard deviation of the differences. The allocated VI can
 40 substantially differ according to the chosen number of trees to grow (*ntree*), the
 41 minimum size of the terminal nodes (*nodesize*), or the number of input variables at each
 42 split (*mtry*) (Genuer et al. 2010; Grömping 2009). This last parameter has been
 43 described as the most critical one; if *mtry* = 1, the splitting variable would be
 44 determined completely randomly; whereas a *mtry* = p (maximum number of variables)
 45 would eliminate the previously described first aspect of randomness, and the possibility
 46 of some independent variables –related to the dependent variable but correlated to a
 47 stronger regressor– to become the basis of splitting. A usually recommended value on a
 48 regression is *mtry* = $p/3$ because lower correlation between individual trees improves

¹ A random forest is random in two complementary ways: (i) each tree is based on a random subset of the observations (in our case, cells), and (ii) each split within each tree is created based on a random subset of candidate independent variables.

prediction accuracy (Liaw & Wiener 2002). However, as the *mtry* values depend on the model and the correlation between independent variables (Breiman 2001; Grömping 2009), we set a *mtry*² that minimize the OOB-MSE of the model (and a *ntree* = 500, and a *nodesize* = 1).

RESULTS

² For Latin America & Caribbean, North America & Australia–NZ and Sub-Saharan Africa *mtry* = 5; for the globe and East Europe & Central Asia *mtry* = 4; for Middle East & North Africa and West Europe *mtry* = 3; and for South-east Asia & Oceania *mtry* = 2.

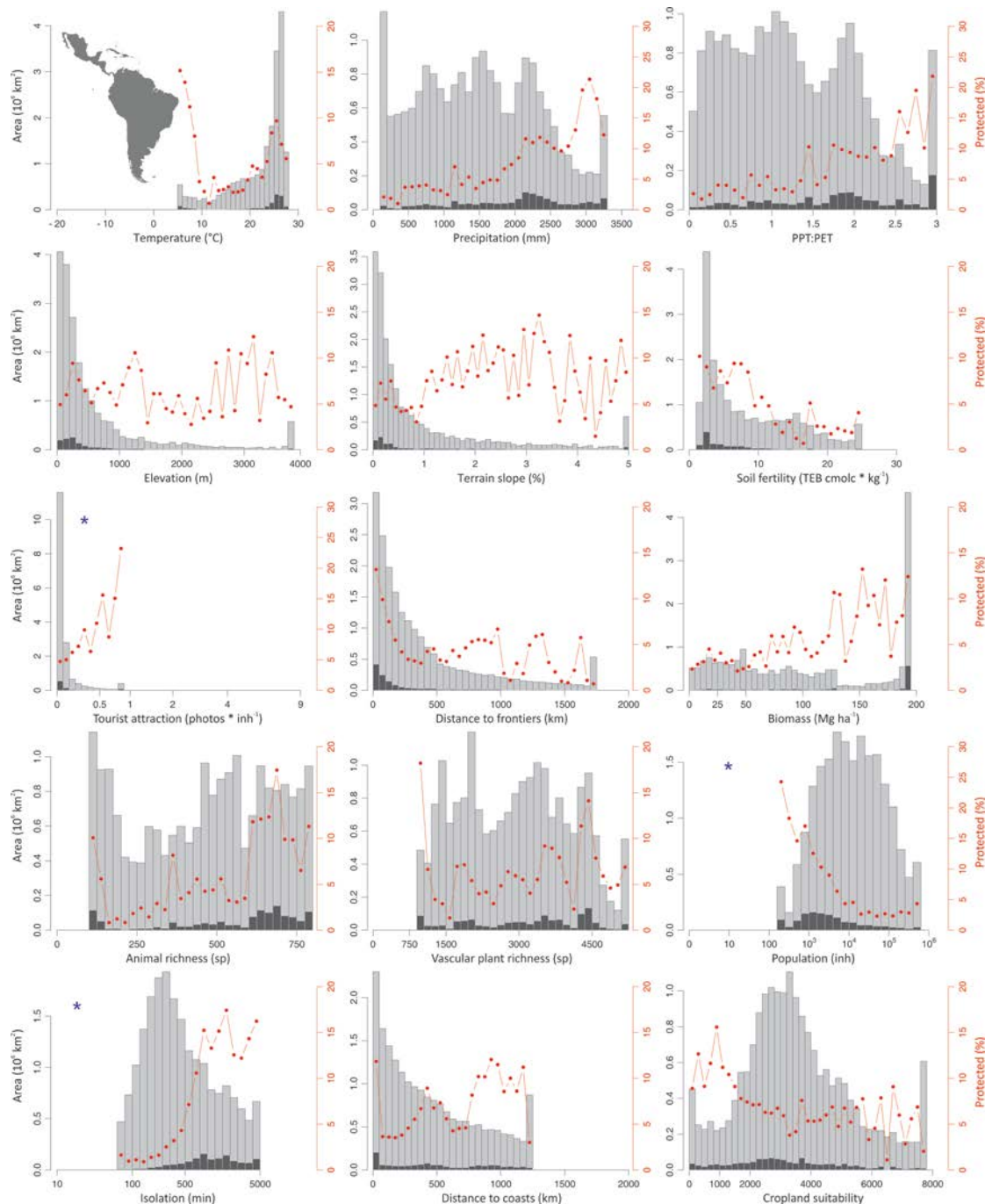


Figure S1.

Title: Regional distribution of protected areas.

Legend: Regional distribution of protected areas along biophysical, human, and biological gradients. Histograms depict the regional area in each class of the 15 independent variables (light gray bars), the area under protection in each class (intervals in the histograms) of the independent variable (dark gray bars), and the fraction under protection of the class of the independent variable (red dots and lines). Lower and upper classes were grouped using the percentile values 0.025 and 0.975 of the independent variable. Blue asterisks denote that histograms are generated with the $\log_{10}$ transformed

independent variable, and thus do not correspond with the same data used for statistical analyses. Green asterisks denote that classes in histograms were divided in order reach ≥ 8 j intervals in the statistical analyses. In order or appearance (and shown by inset maps): East Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, North America & Australia–NZ, South-east Asia & Oceania, Sub-Saharan Africa, and West Europe.

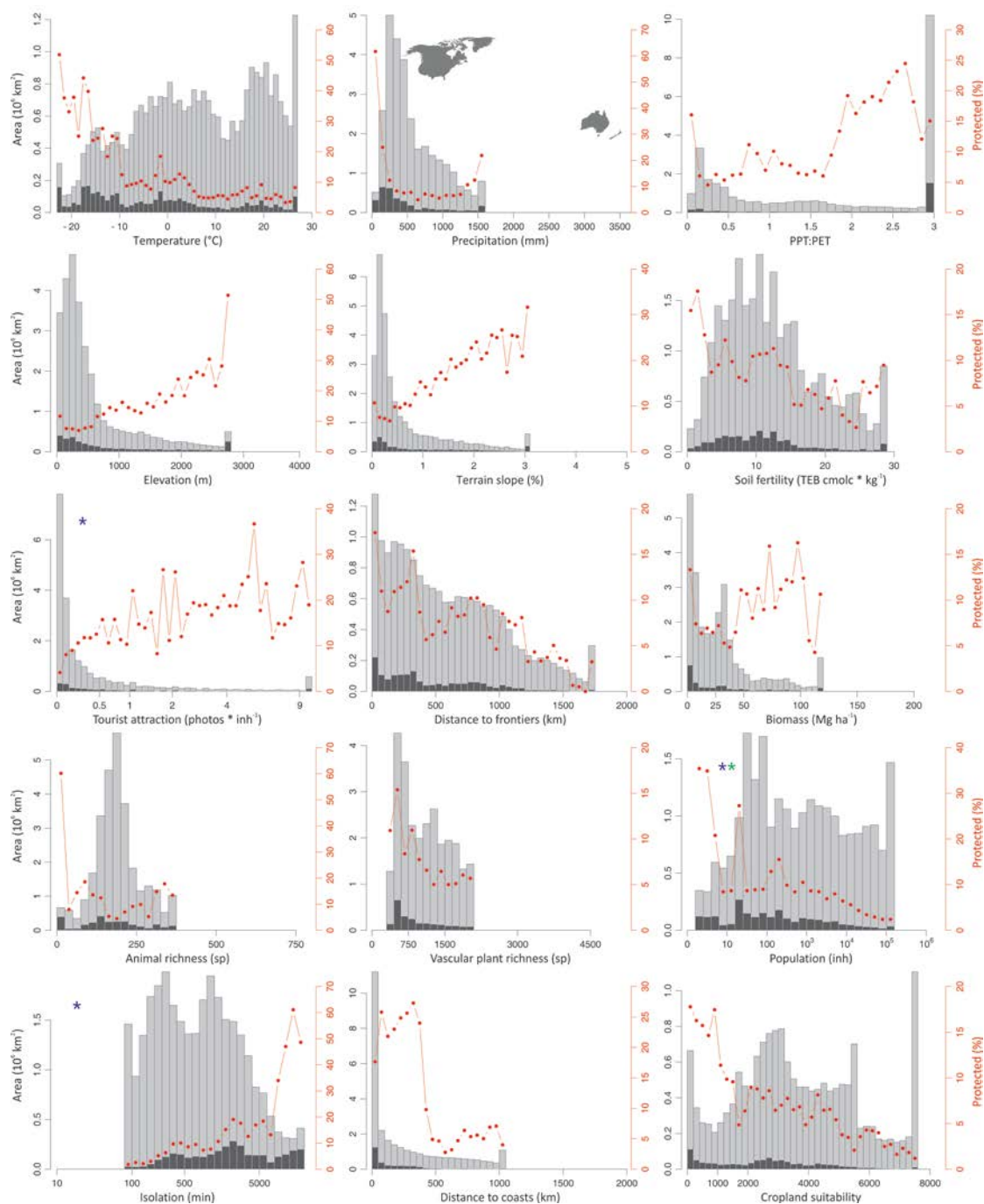


Figure S1. cont.

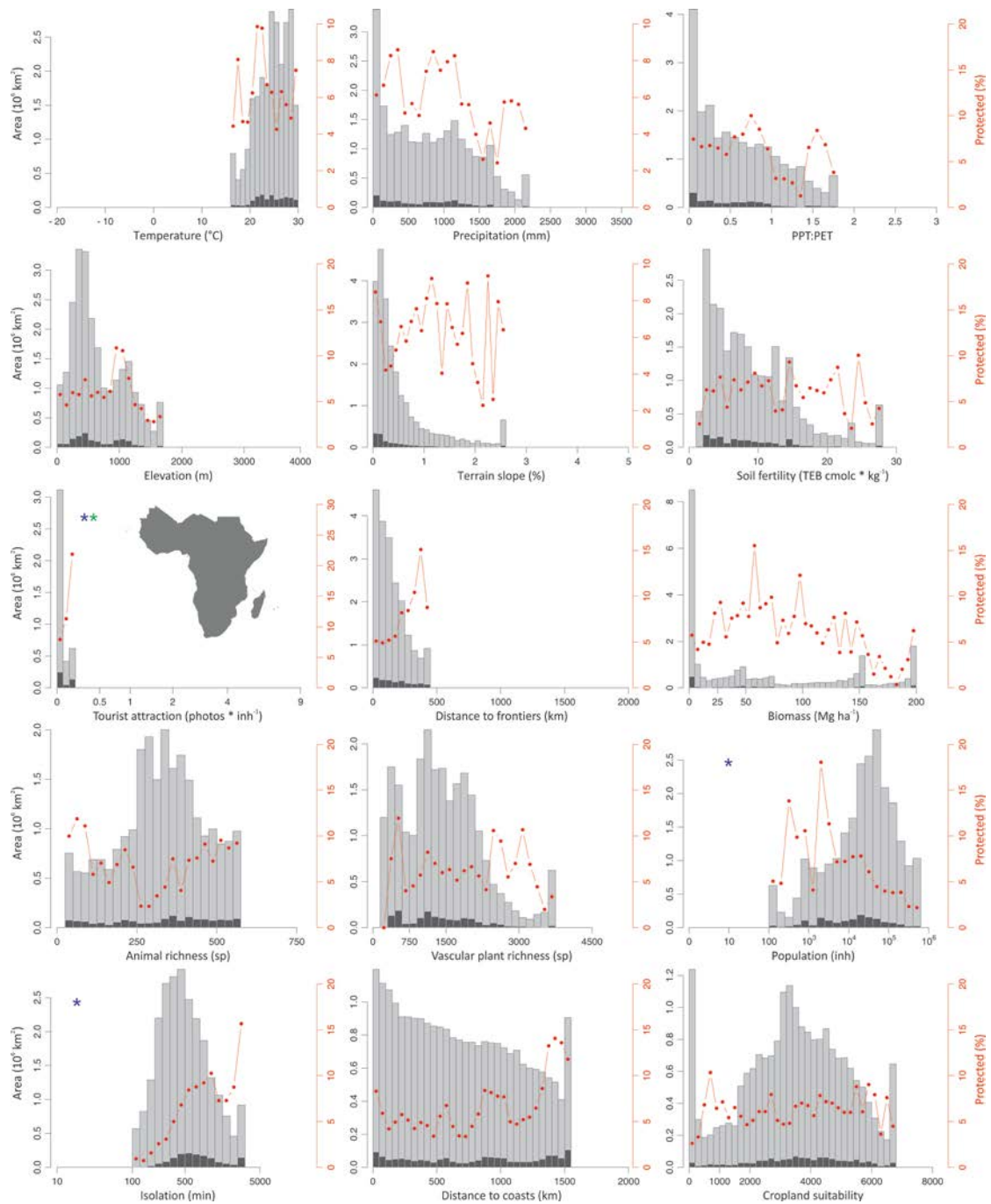


Figure S1. cont.

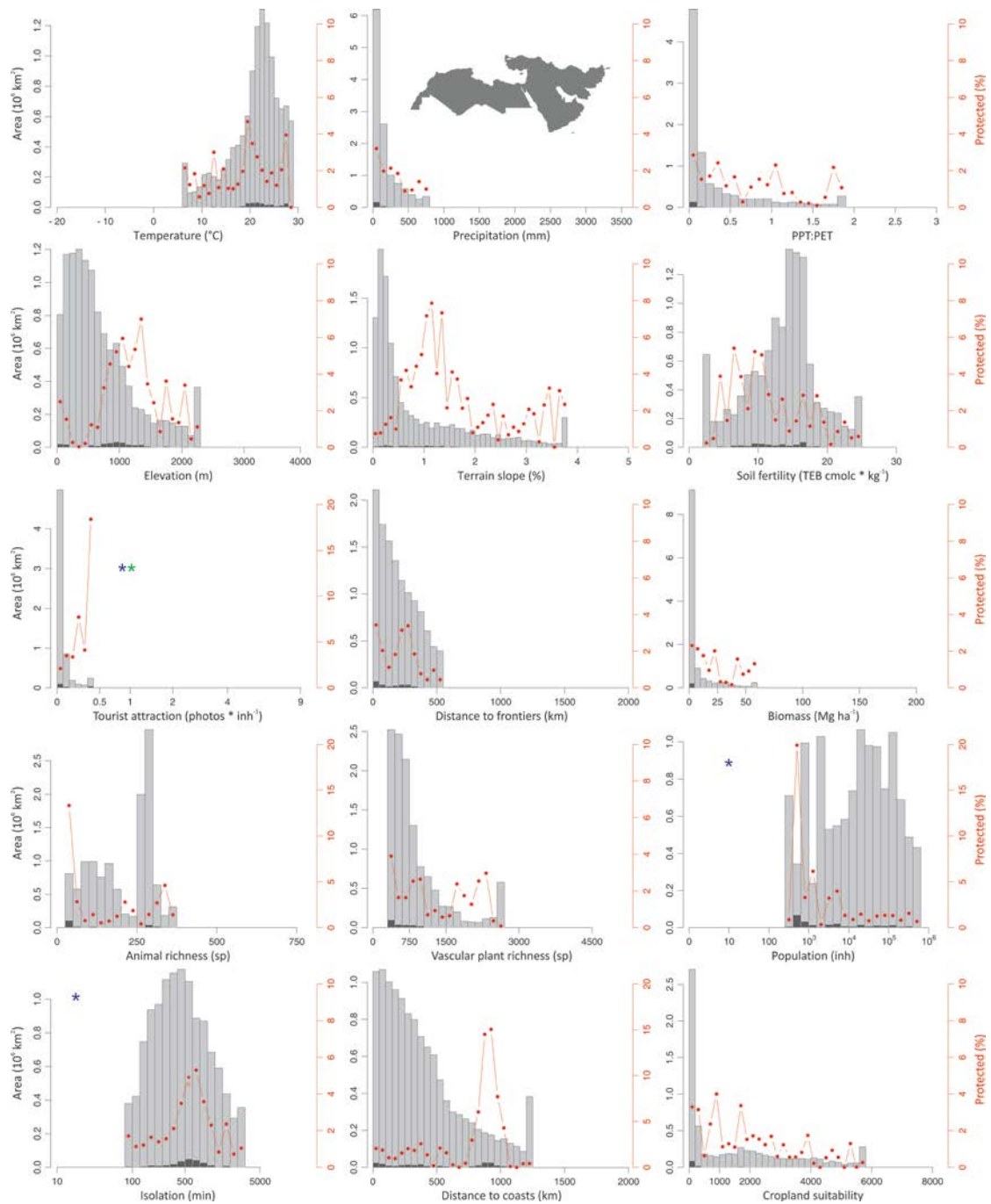


Figure S1. cont.

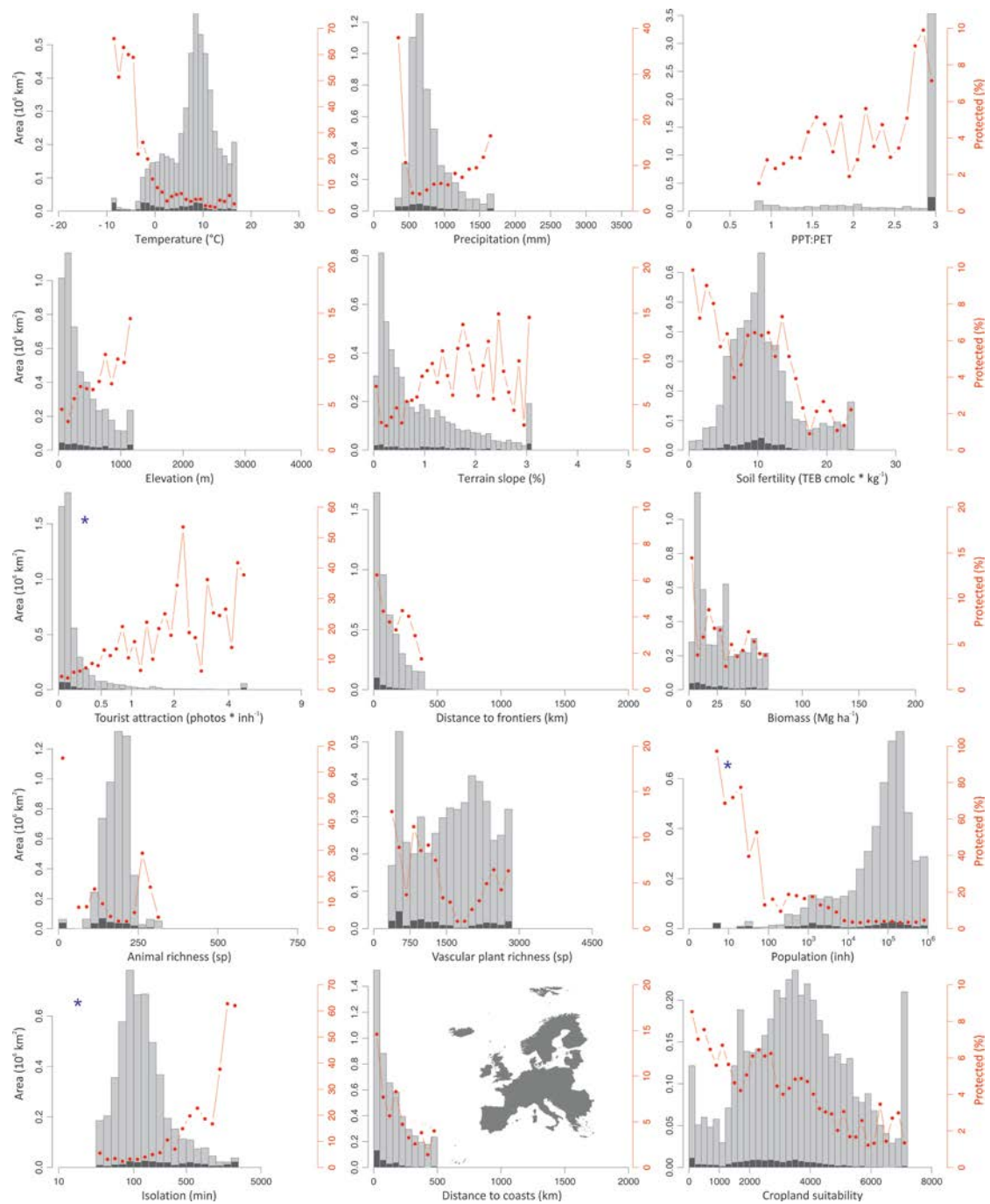


Figure S1. cont.

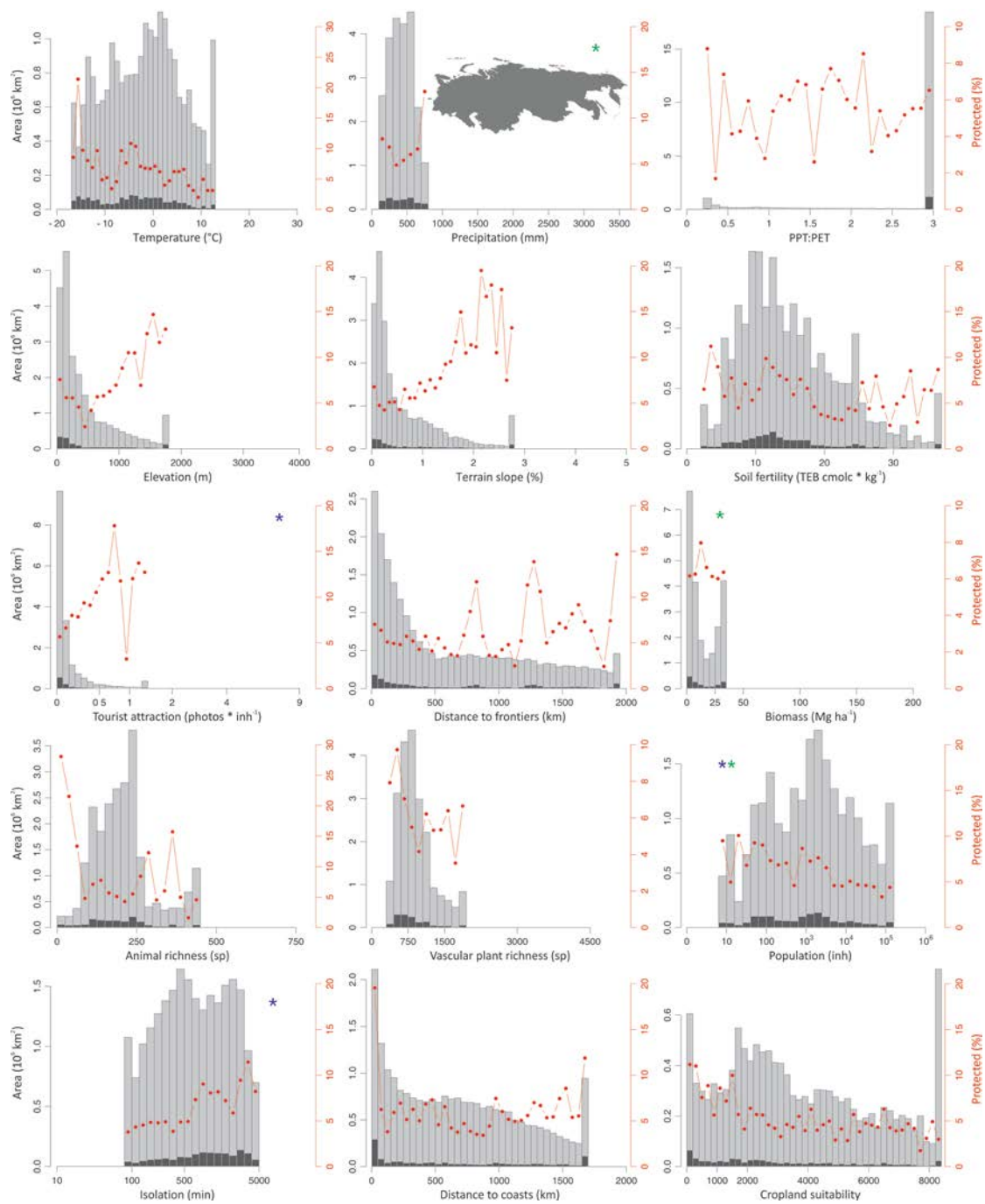


Figure S1. cont.

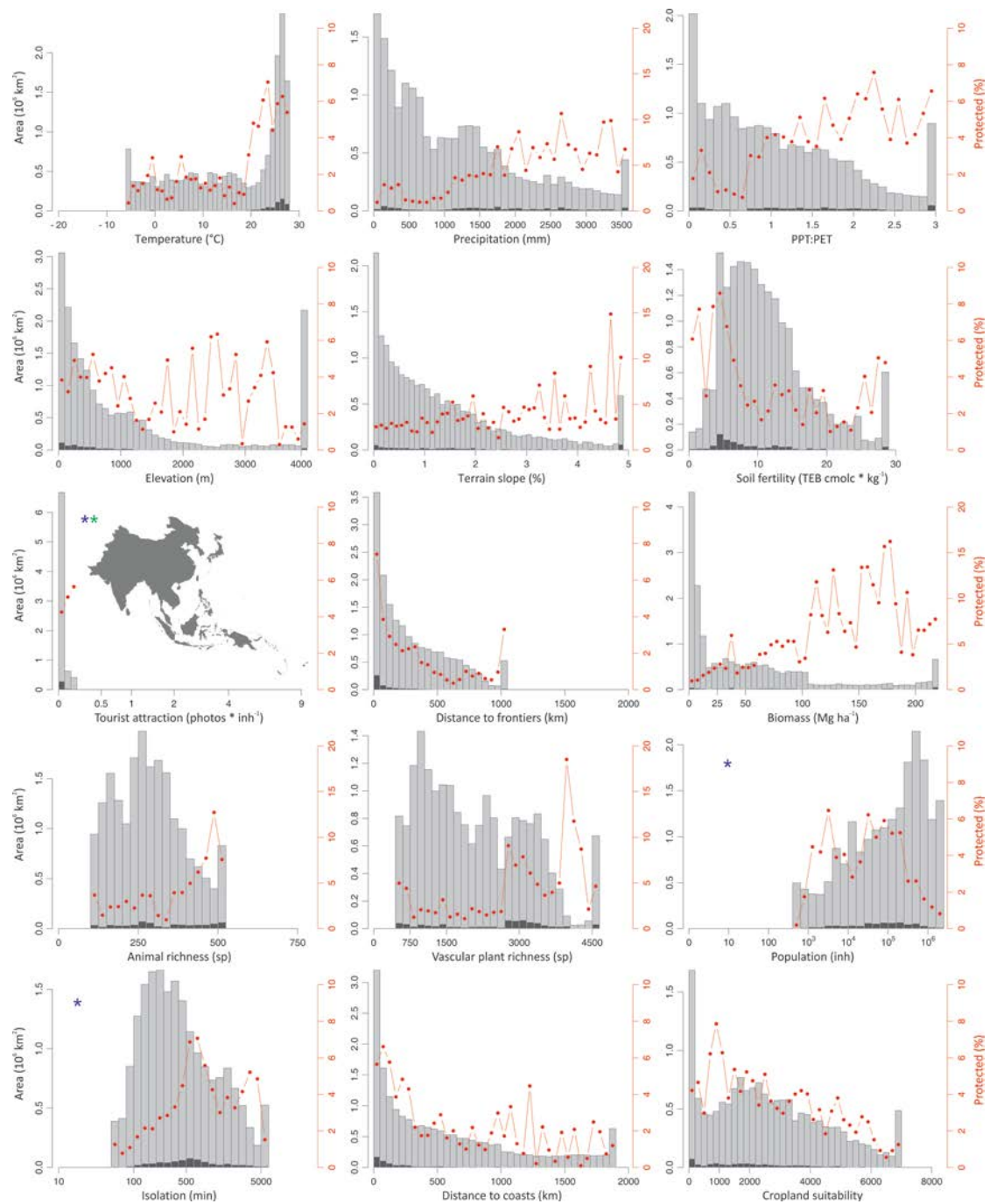


Figure S1. cont.

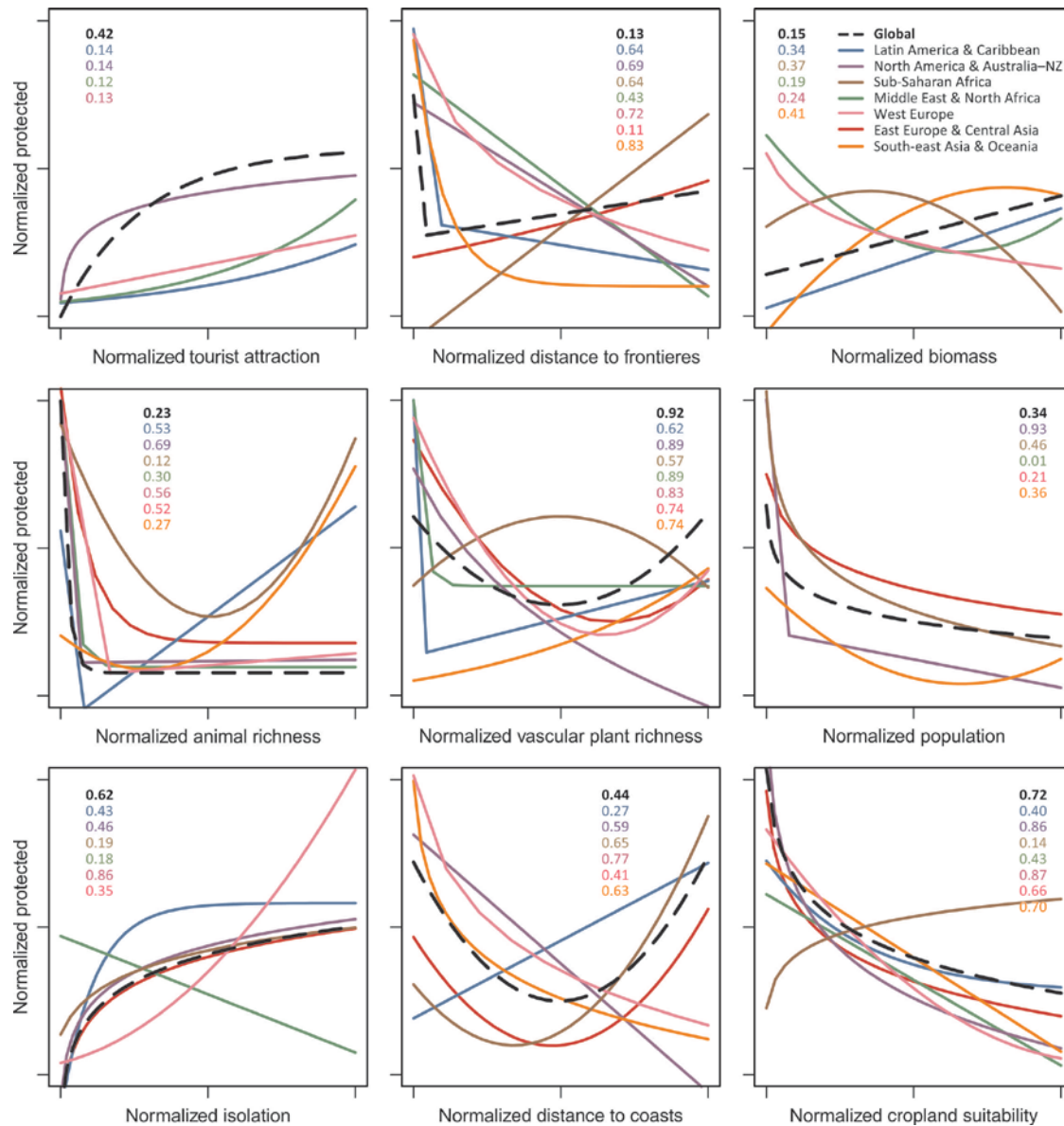
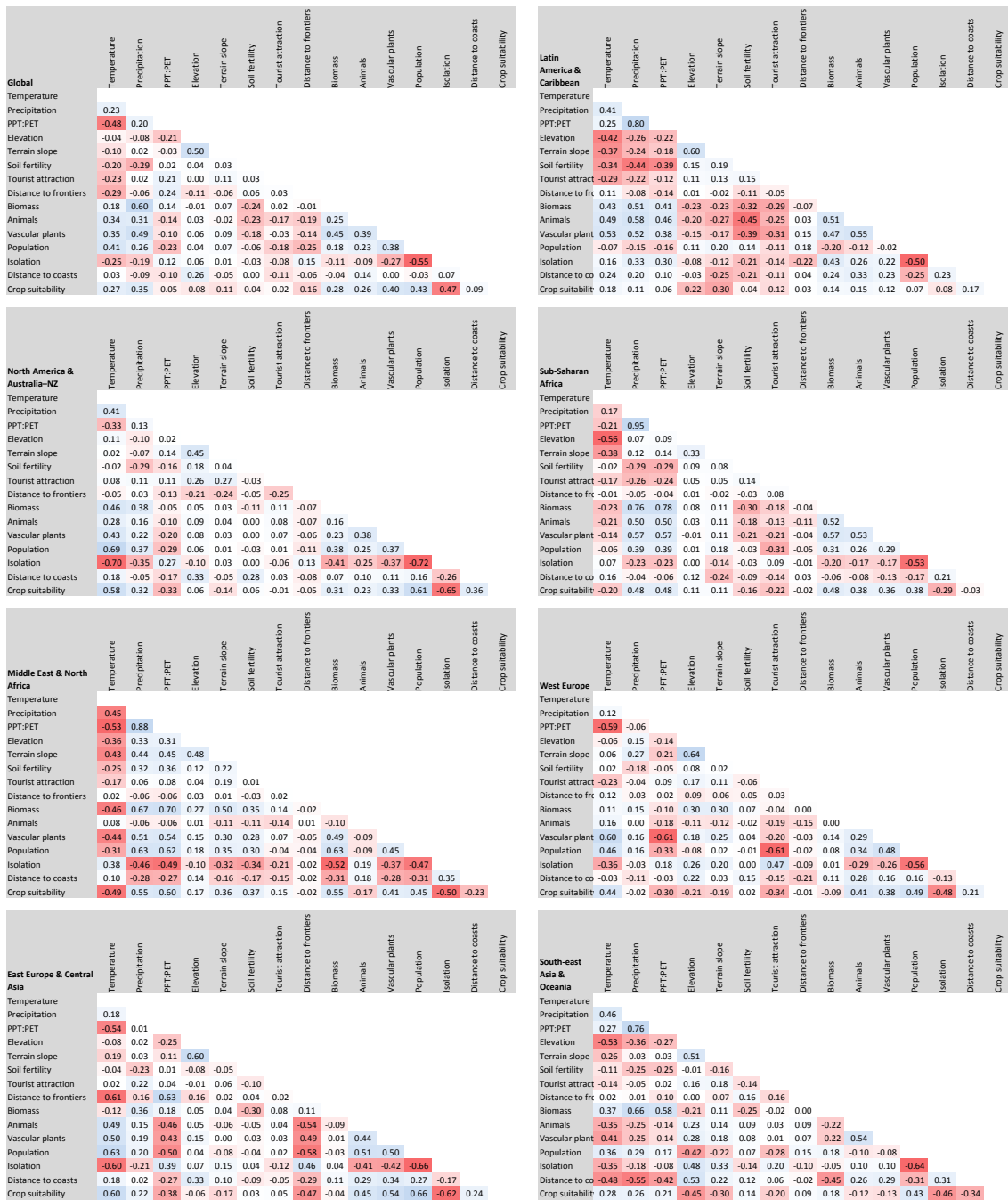


Figure S2.

Title: Models of the fraction under protection along human and biological gradients.

Legend: Models of the fraction under protection along human and biological variables (red lines in Fig. S1) related to preferential motivations and opportunistic forces, at global and regional levels. Numbers represent pseudo-R² values. Models with a pseudo-R² < 0.1 were not plotted for simplification purposes. Plot axes were normalized using the ranges of the values of fraction and of the independent variables.



	Latin America & Caribbean	North America & Australia—NZ	Sub-Saharan Africa	Middle East & North Africa	West Europe	East Europe & Central Asia	South-east Asia & Oceania
GDP (2014 US\$, 2006-2012)	9.90E+11	6.06E+12	4.72E+10	2.52E+11	9.25E+11	1.11E+12	3.12E+12
Income per person (2000 US\$, 2006-2011)	5030	29641	780	4838	19959	2515	2490
Human Development Index (2013)	0.75	0.92	0.47	0.72	0.87	0.76	0.67
Survival vs. self-expression values (2010-2014)	0.41	1.70	-0.18	-0.76	0.65	-1.18	-0.58
Traditional vs. secular-rational values (2010-2014)	-0.96	-0.02	-0.93	-0.99	0.63	0.43	0.60
Date of first protected area	1907	1872	1895	1933	1838	1819	1889
PA pre-formation of the modern state (%)	2.7	35.3	44.3	0.9	31.8	54.3	2.4
Protected areas (%)	6.6	11.4	6.3	2.1	5.1	6.8	3.2
Protected areas (number)	1646	24538	771	219	41805	3447	1467
PA budget relative to GDP (‰, 1990-2000)	0.11	0.32	0.49	0.05	0.18	nd	0.11
PADDD vs. total protected(‰)	2.5	26.1	9.3	0.0	0.0	6.0	1.0

Figure S4.

Title: Regional cultural and conservation aspects.

Legend: General cultural and conservation aspects across regions. Variables 1-5 came from averaging national level statistical data, weighted by country area. Sources: gross domestic product (GDP) and income per person (The World Bank 2014); Human Development Index (UNPD 2014); survival vs. self-expression values and traditional vs. secular-rational values (WVS 2014); national independence days (www.wikipedia.org); protected area downgrading, downsizing, and degazettement (PADDD) (World Wildlife Foundation 2014); protected areas budget (James et al. 1999); data concerning protected areas (IUCN and UNEP-WCMC 2013). Variables 4 and 5 are unitless, and when higher the values, the higher the relative importance of self-expression or secular-rational values. Acronym: PA, protected area.

	Global	Latin America & Caribbean	North America & Australia—NZ	Sub-Saharan Africa	Middle East & North Africa	West Europe	East Europe & Central Asia	South-east Asia & Oceania
Temperature	8.5	5.3	14.0	6.4	1.9	17.6	6.6	2.4
Precipitation	7.2	7.7	13.2	6.0	1.3	10.1	7.2	4.7
PPT:PET	7.2	7.5	11.9	6.1	1.3	4.3	5.5	4.0
Elevation	9.2	6.5	17.6	5.9	2.6	7.7	7.9	3.1
Terrain slope	8.3	7.9	17.4	6.3	2.5	7.7	9.4	4.0
Soil fertility	5.7	4.9	8.5	6.0	2.1	4.9	6.1	3.1

Figure S5.

Title: Protected fraction (%) of each biophysical gradient.

Legend: Average of the fraction under protection (%) for the intervals (in the histograms) of each biophysical independent variable at global and regional levels. Green cells indicate a fraction under protection ≥ 17 , indicating an achievement of the Aichi Biodiversity target 11 (Strategic Plan 2011-2020). The larger the gray bars, the farthest from the target.

REFERENCES

- Akaike H. 1974. A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19:716–723.
- Allen RG, Pereira LS, Raes D, and Smith MD. 2004. *Crop evapotranspiration. Guidelines for computing crop water requirements*. Roma: FAO.
- Badshah MA, and Bhadran CAR. 1962. National Parks: Their Principles and Purposes. In: Adams AB, ed. *First World Conference on National Parks*. Washington, USA: National Park Service, 23-34.
- Batjes N. 2006. ISRIC-WISE derived soil properties on a 5 by 5 global grid (Version 1.1). Report 2006/02, ISRIC – World Soil Information Wageningen, Netherlands.
- Belbin L. 1993. Environmental representativeness: Regional partitioning and reserve selection. *Biological Conservation* 66:223-230. [http://dx.doi.org/10.1016/0006-3207\(93\)90007-N](http://dx.doi.org/10.1016/0006-3207(93)90007-N)
- Bhagwat SA, and Rutte C. 2006. Sacred groves: Potential for biodiversity management. *Frontiers in Ecology and the Environment* 4:519-524.
- Bourlière F. 1962. Science and Parks in the Tropics In: Adams AB, ed. *First World Conference on National Parks*. Washington, USA: National Park Service, 64-68.
- Breiman L. 2001. Random Forests. *Machine Learning* 45:5-32.
- CIESIN-CIAT. 2005. Gridded Population of the World Version 3 (GPWv3): Population Grids. Palisades, USA: Socioeconomic Data and Applications Center (SEDAC), Columbia University.
- Costanza R, d' Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo JM, Raskin RG, Sutton P, and van den Belt M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 357:253-260.
- Eagles PFJ, McCool SF, and Haynes CD. 2002. Sustainable tourism in protected areas: Guidelines for planning and management. In: Phillips A, editor. *Best Practice Protected Area Guidelines Series No 8*. Gland, Switzerland and Cambridge, UK: International Union for Conservation of Nature and Natural Resources, United Nations Environment Programme, & World Tourism Organization p191.
- FAO/IIASA. 2011. Global Agro-ecological Zones (GAEZ v3.0). Roma, Italia and Laxenburg, Austria: FAO and IIASA.
- Faraway JJ. 2006. *Extending the Linear Model with R: Generalized Linear, Mixed Effects and Nonparametric Regression Models*. Boca Raton, USA: Chapman & Hall/CRC.
- Genuer R, Poggi JM, and Tuleau-Malot C. 2010. Variable selection using random forests. *Pattern Recognition Letters* 31:2225-2236.

- Grömping U. 2009. Variable importance assessment in regression: linear regression versus random forest. *The American statistician* 63:308.
- Hoekstra JM, Boucher TM, Ricketts TH, and Roberts C. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters* 8:23-29.
- Holdridge LR. 1947. Determination of world plant formations from simple climatic data. *Science* 105:367-368.
- IUCN and UNEP-WCMC. 2013. World Database on Protected Areas (WDPA) Annual Release 2013 (web download version). Cambridge, UK.
- James AN, Green MJ, Beverley, and Paine JR. 1999. A Global Review of Protected Area Budgets and Staff. WCMC Biodiversity Series No10. Cambridge, UK: IUCN World Commission on Protected Areas (WCPA) - WCMC. p 46.
- Jenkins CN, Pimm SL, and Joppa LN. 2013. Global patterns of terrestrial vertebrate diversity and conservation. *Proceedings of the National Academy of Sciences of the United States of America* 110:E2602-2610.
- Kareiva P, and Marvier M. 2003. Conserving Biodiversity Coldspots. *American Scientist* 91:344-351.
- Kreft H, and Jetz W. 2007. Global patterns and determinants of vascular plant diversity. *Proceedings of the National Academy of Sciences of the United States of America* 104:5925-5930.
- Liaw A, and Wiener M. 2002. Classification and Regression by randomForest. *R News* 2:18-22.
- Loreau M. 2014. Reconciling utilitarian and non-utilitarian approaches to biodiversity conservation. *Ethics in Science and Environmental Politics* 14:27-32. 10.3354/esep00149
- Margules CR, and Pressey RL. 2000. Systematic conservation planning. *Nature* 405:243-253.
- McKercher B. 1996. Differences between Tourism and Recreation in Parks. *Annals of Tourism Research* 23:563-575. [http://dx.doi.org/10.1016/0160-7383\(96\)00002-3](http://dx.doi.org/10.1016/0160-7383(96)00002-3)
- McNeely JA, Harrison J, and Dingwall PR. 1994. Introduction: protected areas in the modern world. In: McNeely JA, Harrison J, and Dingwall PR, eds. *Protecting nature: regional reviews of protected areas*. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources (IUCN).
- Mulholland G, and Eagles PFJ. 2002. African parks: combining fiscal and ecological sustainability. *Parks* 12:42-49.
- Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, and Kent J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403:853-858.
- Nelson A. 2008. Estimated travel time to the nearest city of 50,000 or more people in year 2000. Ispra, Italy: Global Environment Monitoring Unit - Joint Research Centre of the European Commission.
- New M, Lister D, Hulme M, and Makin I. 2002. A high-resolution data set of surface climate over global land areas. *Climate Research* 21:1-25.
- Parrish JD, Braun DP, and Unnasch RS. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. *BioScience* 53:851-860.
- Pressey RL. 1994. Ad hoc reservations: Forward or backward steps in developing representative reserve systems? *Conservation Biology* 8:662-668.
- Ruesch A, and Gibbs HK. 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000. Oak Ridge, USA: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory.
- SCBD. 2010. COP-10 Decision X/2. Secretariat of the convention on biological diversity. Nagoya, Japan.

- 218 Schimper AFW, Balfour IB, Fisher WR, and Groom P. 1903. *Plant-geography upon a*
219 *physiological basis*. Oxford, UK: Clarendon Press.
- 220 Terborgh J, and Winter B. 1983. A method for siting parks and reserves with special
221 reference to Columbia and Ecuador. *Biological Conservation* 27:45-58.
- 222 The World Bank. 2014. World Development Indicators.
- 223 UNPD. 2014. Human Development Report 2014. Sustaining Human Progress:
224 Reducing Vulnerabilities and Building Resilience. New York, USA: United
225 Nations Development Programme. p 226.
- 226 USGS. 2004. SRTM Elevation Data. University of Maryland. College Park, USA: US
227 Geological Survey.
- 228 Woodward FI, Lomas MR, and Kelly CK. 2004. Global climate and the distribution of
229 plant biomes. *Philosophical Transactions of the Royal Society B: Biological*
230 *Sciences* 359:1465-1476.
- 231 World Wildlife Foundation. 2014. PADDDtracker.org Data Release Version 1.0. World
232 Wildlife Foundation.
- 233 WVS. 2014. World Values Survey Association (www.worldvaluessurvey.org). Wave 6
234 2010-2014 Aggregate File Producer: Asep/JDS. OFFICIAL AGGREGATE
235 v.20150418. Madrid, Spain.
- 236 Zbicz DC, and Green MJB. 1997. Status of the world's transfrontier protected areas.
237 *Parks* 7:510.