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Opportunities drive the global distribution of protected areas

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Background. The establishment of protected areas, regarded today as a cornerstone of nature conservation, resulted from a multiple array of motivations and opportunities. We explore at global and regional levels, the current distribution of protected areas along biophysical, human, and biological gradients, and assess to what extent protection pursued (i) a balanced representation of biophysical environments, (ii) a set of preferred conditions (biological, spiritual, economical, or geopolitical) or (iii) lands where conservation opportunities exist. Methods. We described with histograms the distribution of terrestrial protected areas along physical, human, and biological independent gradients. Linear and non-linear regressions and correlations led to a general description of sign, shape, and strength of the relationships; a random forest analysis led to a importance ranking of the variables related to individual preferential motivations and opportunistic forces; and an evenness metric seized the strength of variables related to individual representative motivations. Results. We found that globally protection was primarily driven by the opportunities provided by isolation and a low population density (variable importance = 34.6 and 19.9, respectively). Preferences played a secondary role, with a bias towards tourist attractions and international borders (variable importance = 12.7 and 3.4, respectively). Opportunities shaped protection strongly in North America & Australia–NZ and Latin America & Caribbean, while the representativeness of biophysical environments was higher in Sub-Saharan Africa (1.3 times the average of other regions). Discussion. Our results suggest that in spite of being a top priority in land conservation agendas, environmental representativeness and biodiversity protection are still minor players driving protection at global and regional levels, and that the attempts to increase their relevance will necessarily have to recognize the predominant weight that other drivers are playing in the protected areas deployment.
Opportunities drive the global distribution of protected areas

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ABSTRACT

Background. The establishment of protected areas, regarded today as a cornerstone of nature conservation, resulted from a multiple array of motivations and opportunities. We explore at global and regional levels, the current distribution of protected areas along biophysical, human, and biological gradients, and assess to what extent protection pursued (i) a balanced representation of biophysical environments, (ii) a set of preferred conditions (biological, spiritual, economical, or geopolitical) or (iii) lands where conservation opportunities exist.

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Results. We found that globally protection was primarily driven by the opportunities provided by isolation and a low population density (variable importance = 34.6 and 19.9, respectively). Preferences played a secondary role, with a bias towards tourist attractions and international borders (variable importance = 12.7 and 3.4, respectively). Opportunities shaped protection strongly in North America & Australia–NZ and Latin America & Caribbean, while the representativeness of biophysical environments was higher in Sub-Saharan Africa (1.3 times the average of other regions).

Discussion. Our results suggest that in spite of being a top priority in land conservation agendas, environmental representativeness and biodiversity protection are still minor players driving protection at global and regional levels, and that the attempts to increase their relevance will necessarily have to recognize the predominant weight that other drivers are playing in the protected areas deployment.

INTRODUCTION

Historically and throughout the world, societies have set pieces of land aside from conventional uses, conferring them a special management status aimed at protecting particular natural or cultural values (McNeely et al. 1994). In this way, hilltops, old-growth forests, or seashores maintained their biodiversity, scenic attributes, or production of ecological services. In the last century, simultaneously with the raising pressures over land resources (Ellis et al. 2013; Vitousek et al. 1997), these protected areas have increased in numbers and total area significantly. From just a small handful of locations at the end of the 19th century to thousands nowadays, protection encompasses in areas explicitly designated for nature protection –IUCN categories I-IV (IUCN 1994)– 6.7% of the world’s land surface (1.4 x 10^8 km^2), excluding Antarctica (Fig. 1).

The current distribution of protected areas responds thus, to a deliberate process guided by a complex interplay of motivations related to perceived societal benefits (Margules & Pressey 2000; McNeely et al. 1994; Pressey 1994; Watson et al. 2014). The strength of different motivations changed through history and across territories (Mace 2014; Marinaro et al. 2012; Sellars 1997; Wirth 1962). Many of the protected areas set up in the late 19th and early 20th
centuries responded to practical interests such as tourism or iconic features of the landscapes. However, since the second half of the 20\textsuperscript{th} century, protection has been influenced by a widespread agreement on the importance of maintaining nature in general and biodiversity in particular. Therefore present-day expansion of protected networks aims to include areas of high species richness or underrepresented ecological or biophysical conditions. Ultimately, we classify motivations as preferential, preserving locally biological, spiritual, economical, or geopolitical ideal conditions; or representative, preserving a balanced sampling of biophysical environments (Lovejoy 2006; Pressey 1994) (Table S1). The two groups of motivations would interact with different opportunistic forces of conservation, as protected areas are frequently deployed in lands that are unlikely to face human interventions, at least at the time of their establishment (Aycrigg et al. 2013; Durán et al. 2013; Joppa & Pfaff 2009). Consequently, protection could be biased towards unproductive or isolated areas (e.g. extremely cold/dry), leaving other territories inadequately protected despite their potential conservation requirements (e.g. temperate, subhumid areas) (Chape et al. 2005; Hoekstra et al. 2005; Joppa & Pfaff 2009; Margules & Pressey 2000; McNeely & Schutyser 2003; Pressey 1994; Scott 1993).

Most research about the spatial distribution of protected areas has been directed to the effectiveness of current networks encompassing biodiversity (Brooks et al. 2004; Rodrigues et al. 2004a; Rodrigues et al. 2004b; Scott 1993) and representing biogeographic (ecoregions, biomes, realms) (Barr et al. 2011; Chape et al. 2005; Jenkins & Joppa 2009; McNeely et al. 1994; Mücher et al. 2009; Watson et al. 2014) or anthropogenic units (Martin et al. 2014). However, up to this point, few studies have addressed the relative importance that different forces may have had on the deployment of protected areas, leading to a spatially and thematically fragmented understanding (Joppa & Pfaff 2009). Here, we characterized the current distribution of terrestrial protected areas –IUCN categories I-IV (IUCN 1994)– in relation to biophysical, human, and biological variables. By associating these variables to representative motivations, preferential motivations, and opportunistic forces, we assessed their effect and relative importance at regional and global levels (Tables S1 and S2). While these drivers are likely to coexist, their predominance should yield singular measurable protection patterns: (i) If representative motivations prevail, two alternative patterns are expected, depending on whether protection targets a uniform fraction or on a uniform absolute area of biophysical environments. Seeking a uniform protected fraction leads protected lands to be mainly composed by the most abundant
environments (hereafter, “abundance-based representativeness”) (Fig. 2A). Alternatively, seeking a uniform absolute area leads protected lands to be composed by common as well as rare environments (hereafter, “quota-based representativeness”) (Fig. 2B). (ii) If preferential motivations prevail, protection would be geographically biased towards biological, spiritual, economical, or geopolitical values (e.g. species diversity, frontiers) (Fig. 2C). (iii) Finally, biases would also arise if opportunistic forces prevail, with protected areas having greater chances to get established in lands of poor productive potential and/or low human presence (Fig. 2C). Our analyses included linear and non-linear regressions, correlations, random forests, and evenness metrics, taking advantage of available spatial datasets.

METHODS

Data sources

The location of protected areas came from the “World Database on Protected Areas” – Annual Release 2013– (IUCN and UNEP-WCMC 2013). We considered only terrestrial areas explicitly designated for nature protection, i.e. strict nature reserve, wilderness areas, national parks, natural monuments or features, and habitat/species management areas –categories I to IV– (IUCN 1994). We compiled a database of 15 biophysical, human, and biological variables (Table S2). Even though we included –as far as we know– the most updated and accurate global information, we acknowledge that the precision and stability of results remain to be validated at a local level and along time. We excluded Antarctica from all analyses.

Sampling procedure

We explored the distribution of protected areas at global and regional levels, considering Latin America & Caribbean, North America & Australia–NZ (New Zealand), Sub-Saharan Africa, Middle East & North Africa, West Europe, East Europe & Central Asia, and South-east Asia & Oceania (Fig. 1). Our regional divisions relied on cultural, historical, and biogeographical factors (adapted from Ellis & Ramankutty 2008; Inglehart & Welzel 2005; McNeely et al. 1994). In order to analyze the links between protected areas and independent variables (Table S2), we summarized all the data in 66,555 contiguous cells of 0.5° x 0.5° (Table S3), excluding those cells with a terrestrial fraction < 5%. Within each cell, we averaged all variables except #9, #12, and #13 (Table S2). By generating a grid, (i) a single sampling scheme
is applied to variables available at different spatial resolutions, (ii) all the existing biophysical and human conditions are scanned, and (iii) the diversity of conditions within a single protected area (due to variable sizes) is avoided. Additionally, (iv) this sampling approach incorporates the conditions outside protected areas on >99.55% of the cells.

**Data analysis**

After summarizing all data within grid cells, we generated 8*15 histograms, (7 regions + globe) * 15 independent variables, containing three sets of information: (i) the absolute area under protection in each j class (intervals in the histograms) of the i independent variable – AREA.PROT--; (ii) the fraction under protection of the class j of the i independent variable – FRAC.PROT--, and (iii) the area in each class of the i independent variables –AREA--; considering a weighted arithmetic mean according to a maximum cell area within each j class.

We conducted all statistical analyses with the AREA.PROT and FRAC.PROT information, while AREA information was shown with a merely descriptive purpose. We assessed the reciprocal associations between the i independent variables through a Kendall’s τ non-parametric test (Whittaker 1987). All calculations were run in RStudio v.0.98.507 (packages Segmented, Scatterplot3d) and Python v.2.7 (packages Scikit-learn, Pandas, Numpy).

In order to explore the relative significance of “abundance-based” and “quota-based” representativeness motivations, we analyzed the existence of a relationship between the FRAC.PROT and AREA.PROT values and 6 biophysical variables (Fig. 2) by means of a modification of the “Shannon evenness” ($H'_i$) (Hill 1973), calculated as:

\[
V_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}
\]

\[
H_i = \sum_{j=1}^{n} V_{ij} \cdot \ln V_{ij}
\]

\[
H'_i = \frac{H_i}{n \cdot \min(V_{ij} \cdot \ln V_{ij})}
\]

where $x_{ij}$ represents the FRAC.PROT and AREA.PROT in the j class of the i independent variables, and n the number of classes on the histogram. $V_{ij}$ is calculated to transform
FRAC.PROT and AREA.PROT into probabilities. In $H'_i$, the numerical effects of an uneven number of classes as well as of despair $x_{ij}$ magnitudes are canceled. The index ranges between 0 and 1, with a value of 1 when $x_{ij}$ is constant along the $i$ gradient.

The modified Shannon evenness indicated the presence of a relationship, but not its behavior given by the shape, sign, and multivariate strength. In this sense, we regressed the FRAC.PROT on the $i$ independent variables related to preferential motivations (e.g. animal richness) and opportunistic forces (e.g. cropland suitability). We ranked the relative importance of these variables by means of a random forest –a machine-learning technique– (Breiman 2001). We excluded biophysical variables from the random forest since their importance would not reflect the importance of the representativeness motivation, but quite the opposite. The variable importance was used with an explanatory and interpretative (rather than predictive) aim (Grömping 2009). See methodological details on Supplementary information.

RESULTS AND DISCUSSION

Globally opportunistic forces prevailed over preferential and representative motivations shaping the current protection patterns, as protection significantly increased towards areas that are isolated, are lightly populated, and have low suitability for cropping (Fig. 3). According to a random forest analysis (Methods), on average, the importance of the variables related to opportunistic forces doubled in significance those related to preferential motivations (Fig. 4). Our results sustain previous global explorations performed at ecoregional- (Loucks et al. 2008) or national- basis (Joppa & Pfaff 2009) about the role of opportunistic forces, and expand current knowledge by jointly considering a wider range of biophysical, human, and biological gradients (some of them unconsidered so far, e.g. distance to frontiers or tourist attraction). At a regional level, this predominance was especially significant in North America & Australia–NZ (by cropland suitability) and Latin America & Caribbean (by isolation) (Figs. 4, S1 and S2), challenging Loucks et al. realms results (Loucks et al. 2008). Opportunistic forces can—with time– lose strength (e.g. by road expansion), stimulating the degradation of the legal status of a protected area, a phenomenon of significant magnitude in the first region, and emergent at the global level (Mascia & Pailler 2011).

Beyond the imprint of opportunistic forces, protection appeared to respond to preferential motivations that entail benefits to individuals or societies (economical, geopolitical, spiritual). In
particular, we found that the tourist attraction of an area (triggered by different motivations; Table S1) was positively related to its level of protection (Figs. 3, S1 and S2), achieving the top of the importance ranking (Fig. 4). Tourism and protection are thus engaged into positive feedbacks due to economical reasons, involving for local communities and countries significant revenues which exceed those from traditional uses (Mulholland & Eagles 2002; Siikamäki et al. 2015). As examples, visitors generate annually US$ $1.5 \times 10^9$ in the highly populated UK’s Lake District National Park (helping to maintain the landscape naturalness, UK National Parks 2015), while –under a contrasting economical/environmental context– US$ $2.1 \times 10^7$ in the parks inhabited by mountain gorillas in Congo DR, Rwanda, and Uganda (Maekawa et al. 2013). Suggesting a causal relationship between the tourism and protection could be controversial, as protection attracts visitors and visitors impel protection; however, most exceptional natural and cultural landscapes around the world are encompassed within protected areas under different IUCN categories.

In the last three decades, the inclusion of new species into protection networks as well as the solution of geographical imbalances (Myers et al. 2000; Olson & Dinerstein; Stattersfield et al. 1998) occupied a primordial place in national and international conservation agendas. However, these motivations are far from being achieved according to our results, probably as they drive protection towards economically productive and unproductive lands (Margules & Pressey 2000). As a measure on how biological conservation was unrelated to protection, we found that the more intensely protected lands were the poorer in animal and vascular plant species –globally and regionally– (Figs. 3 and S1). Both richness measures were positively correlated with cropland suitability at the global level (Kendall’s $\tau = 0.26$ for animals and 0.40 for plants, Fig. S3) revealing how the conflict between this preference and opportunities exacerbates the current biodiversity crisis (Hoekstra et al. 2005; Rodrigues et al. 2004a; Rodrigues et al. 2004b; Venter et al. 2014). The single exception to these findings appeared in South-east Asia & Oceania (Fig. S1), most likely due to the considerable protected systems of the highly-diverse Bhutan, Thailand, Cambodia, and Sri Lanka (Fig. 1) (though see Sodhi et al. 2004). Interestingly, Loucks et al. (Loucks et al. 2008) found the negative relationship between species richness and protection only at the global level and for the Neotropical realm, but not for the remaining 5 realms, a discrepancy probably related to methodological differences (i.e. ecoregion vs. grid cell samples).
As a measure on how representativeness remains unachieved, we found large biases in the distribution of protected areas along biophysical gradients, with an overrepresentation of lands with extreme climates (polar, arid or very humid), high elevations, complex topographies, and unfertile soils (e.g. Northeast Greenland NP, Denmark; Tassili n'Ajjer NP, Algeria; Figs. 3 and S1). Even under this context, and in order to measure and compare the current degree of representativeness, we explored the biophysical biases through a evenness index (Methods). Globally and regionally protection was closer to an abundance- rather than a quota-based representativeness (1.7-times higher, Fig. 5), implying that networks of protected areas tended to be composed by the most abundant environments. Regionally, the highest abundance-based representativeness was accomplished by Sub-Saharan Africa and to a lesser extent by East Europe & Central Asia (surpassing global values), while the highest quota-based representativeness by West Europe (Fig. 5). The representativeness levels were lower and similar in the remaining regions, even the strong differences in their total protected fraction, which spans from 2.1% in Middle East & North Africa to 11.4% in North America & Australia–NZ (Figs. S1 and S4).

Independently of which representativeness prevailed, the analysis of protection along biophysical gradients offers an alternative insight about the achievement of uniform protection targets. Among them, the influential Convention on Biological Diversity aimed that > 17% of terrestrial "areas" (i.e. biogeographical units) needed to be included in protected systems by 2020 (SCBD 2010). According to our results, globally this target is far from being a reality, while regionally, only North America & Australia–NZ and West Europe accomplished it in terms of relief and thermal gradients, respectively (Fig. S5) –considering exclusively IUCN categories I-IV (IUCN 1994)–. The predominance of this abundance-based representativeness in conservation agendas (and in literature) implies that the environments or geographic units of small extent are unintentionally penalized (e.g. any fraction could involve just a few square kilometers for small islands). The concept of quota-based representativeness introduced here overcomes this problem (at least for the least common conservation foci), broadening what an equal representation should be. In fact, quotas are not new; in political organization, many countries have formal electoral rules which guarantee a minimum participation of minorities (e.g. ethnic, gender), or an equal contribution of subnational to national administrative entities regardless population (Bird 2014). Additionally, the assessment of protection along biophysical
gradients may encourage conservation agencies to base their policies on biophysical gaps as well as on biodiversity gaps, as each environment (and encompassed biological distinctiveness and evolutionary strategies) has per se an equal importance. This complementary conservation approach would ultimately overcome the long-lasting conservation dilemma of hotspot/species-richness vs. coldspot/species-poorness (Kareiva & Marvier 2003; Myers et al. 2000).

Regional differences in the weight of different motivations and opportunistic forces would lie on the hierarchical interactions among direct drivers (e.g. conservation agendas), that – following Lambin et al. (Lambin et al. 2003)– can be conceptualized as:

Motivations and opportunistic forces = \( f(\text{policies and economy, social organization, moral rules}) \);

with

- policies and economy = \( f(\text{agendas, economic/financial contexts, property rights, state-owned lands, infrastructure, governance}) \);
- social organization = \( f(\text{urban-rural interactions, ONG and philanthropists actions}) \);
- moral rules = \( f(\text{importance of religion, priority to environmental protection, deference to authority, trust and tolerance, economic/physical security}) \);

with the functions \( f \) having variable forms at the time of the establishment of protection. Even though direct drivers has been previously linked to the protected fraction on a country-basis approach (McDonald & Boucher 2011), very few studies formulated or assessed their interactions with motivations (Marinaro et al. 2012), identifying an adequate abundance-based representation with strong economies, "modern" societies or states, or extensive and long lasting protection networks. However, North America & Australia–NZ and West Europe, representing these conditions with a pioneering and profuse history of protection (Fig. S4), were surpassed in abundance-based representativeness by other regions, and –at the same time– surpassed others in terms of the weight of opportunistic forces (especially cropland suitability) and preferential motivations (especially tourist attraction). The strength of tourist attraction in these two regions (Figs. 4, S1, and S2) may reflect the combination of an affluent population and the shift of people away from the daily contact or dependence on nature (Pyle 2003).

With an opposite socioeconomic context, Sub-Saharan Africa reached the top of the representativeness ranking, perhaps due to the historical indirect effect of colonial regimes, unconstrained by local social organization and with conservation agendas decoupled from local population needs and wills (Naughton-Treves et al. 2005). In this regard, this region showed the
Historical factors can be ascribed as well to the protection of international frontiers (Table S1), as the hypothesis of armed conflicts had a high relative weight in many new countries around the world (Marinaro et al. 2012). This motivation appeared to be especially meaningful in Latin America & Caribbean and South-east Asia & Oceania, as seen in the large concentration of protected areas within the first hundreds kilometers from borders (Fig. S3) and in the large fraction of post-independence claimed areas (Fig. S4). How the change of these direct drivers might affect the relative strength of motivations and opportunistic forces remains to be explored, especially considering the transition of the promotion and deployment of protected areas from national governments to philanthropists and non-governmental organizations, or the empowerment of local rural populations (McNeely & Schutyser 2003; Naughton-Treves et al. 2005).

We should issue certain caveats from our analyses. First, the time dimension has not been explored, yet it could reveal important shifts in the strength of protection motivations and opportunistic forces (Joppa & Pfaff 2009; Marinaro et al. 2012) and in the impact of evolving conservation paradigms (Mace 2014). Second, the sampling approach implies a spatial integration of data (Methods), and thus results can be affected in heterogeneous cells (in terms of land use or biophysical, human, and biological conditions). For example, our analysis does not disentangle the spatial dependences of many small areas that abut urban or productive areas but that were established under locally rough topographies and/or poor soils (e.g. Tijuca NP, Brazil; Sanjay Gandhi NP, India). An assessment based on individual protected areas rather than on cells would solve this problem and would allow exploring the spatial dependences in relation with the geometry of protected areas, as small and large areas have different origins and geographies (Andrew et al. 2011).

CONCLUSIONS

Present-day protected areas are mostly located in zones of relatively low productive value or population pressure, and to a lesser extent in touristic areas. The search for geographical (biophysical) representativeness and biodiversity conservation has still a poor weight shaping the distribution of land protection, in spite of their explicit priority in the debates and agendas of national and international conservation agencies. These trends will probably persist or increase
(McNeely & Schutyser 2003) under the concurrent expansion of protected networks (Jenkins & Joppa 2009) and the increasing pressure over land and resources (Ellis & Ramankutty 2008; Foley et al. 2007). In this sense, representativeness and biodiversity conservation will only be strengthened if coupled with opportunistic forces and the complex array of human preferences (Andrew et al. 2012; Martin et al. 2014). At last, if humans are increasingly considered as modelers and dependents of nature at regional and global levels (Lambin & Meyfroidt 2011; Mace 2014; Margules & Pressey 2000; Martin et al. 2014; van den Born et al. 2001), future conservations policies will need to reconsider the role of goods and services like water provision, or tourism values (Durán et al. 2013) and the basic human need to interact with nature (Loreau 2014; Simaika & Samways 2010; Wilson 1984; Zelenski & Nisbet 2014), which increases happiness and health, and fosters an environmentally sustainable behavior (Simaika & Samways 2010; Zelenski & Nisbet 2014).

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Figure 1

Protected areas fraction on a 0.5° x 0.5° cell basis.

IUCN and UNEP-WCMC (2013) data was summarized within 0.5° x 0.5° contiguous cells, considering IUCN categories I-IV (IUCN 1994). The regions under analysis are depicted with red lines. Regional protected fractions are shown in Fig. S4.
Figure 2

Expected protection patterns according to different forces.

Expected geographic patterns of protected areas according to the three groups of forces. In (A) and (B) “abundance-based” and “quota-based” representative motivations, in (C) preferential motivation and opportunistic forces. Encircled text refers to the expected and tested behavior. Three measurements are shown in the histograms: the area in each class of the independent variables (light gray bars), the area under protection in each $j$ class (intervals in the histograms) of the independent variable (dark gray bars), and the fraction under protection of the $j$ class of the $i$ independent variable (red dots and lines). Only the last two measures were used in the statistical analyses.
Figure 3

Global distribution of protected areas along biophysical, human, and biological gradients. See graphic explanations in Fig. 2. Lower and upper \( j \) classes were grouped using the percentile values 0.025 and 0.975 of the \( i \) independent variable. Blue asterisks denote that histograms were generated with the log\(_{10}\) transformed independent variable, and thus do not correspond with the untransformed data used for statistical analyses. Region-specific histograms are shown in Fig. S1.
Figure 4

Variable importance according to a random forest.

Relative importance of nine variables related to opportunistic and preferential motivations (and their grouped averages), according to the random forest. The importance of animal and vascular plants (depicting the single “biological conservation” motivation, Table S1) were averaged in order to compute the average relative importance of the preferentiality group.

|                   | 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 |
|-------------------|-----------------|---------------------------|-------------------------------|-------------------|-----------------------------|-------------|-----------------------------|-----------------------------|
| Preferentiality   |                 |                           |                               |                   |                             |             |                             |                             |
| Touristiness      | 12.72           | 0.82                      | 6.93                          | 6.28              | 9.29                        | 4.87        | 4.06                        | 3.62                        |
| Distance to frontiers | 3.42           | 10.77                     | 5.94                          | 6.60              | 4.09                        | 5.52        | 7.76                        | 19.68                       |
| Biomass           | 7.31            | 5.40                      | 12.25                         | 5.58              | 3.46                        | 4.81        | 8.40                        | 17.87                       |
| Animal richness   | 9.19            | 6.15                      | 0.14                          | 13.52             | 36.13                       | 10.93       | 7.18                        | 11.35                       |
| Vascular plant richness | 2.54         | 5.16                      | 0.15                          | 5.03              | 10.79                       | 10.12       | 7.28                        | 15.88                       |
| Average           | 7.33            | 5.66                      | 6.32                          | 6.93              | 10.08                       | 6.43        | 6.86                        | 13.70                       |
| Opportunistic     |                 |                           |                               |                   |                             |             |                             |                             |
| Population        | 19.93           | 19.72                     | 15.96                         | 11.93             | 17.17                       | 14.59       | 6.04                        | 6.73                        |
| Isolation         | 34.61           | 47.40                     | 14.18                         | 34.12             | 5.33                        | 12.65       | 21.10                       | 8.92                        |
| Distance to coasts| 7.22            | 2.83                      | 4.81                          | 12.37             | 11.36                       | 3.76        | 16.99                       | 13.07                       |
| Cropland suitability | 3.07          | 1.76                      | 39.63                         | 4.58              | 2.38                        | 32.74       | 21.19                       | 2.89                        |
| Average           | 16.21           | 17.93                     | 18.65                         | 15.75             | 9.06                        | 15.94       | 16.33                       | 7.90                        |
Figure 5

Title: Representativeness according to a modified Shannon evenness.

Modified Shannon evenness ($H'$) for the biophysical variables. The index ranges between 0 and 1, with a value of 1 when $x_{ij}$ is constant along the $i$ gradient. (A) $H'$ values of the area under protection (in light gray), related to the “quota-based representative” motivation; and $H'$ values of the fraction under protection (in red), related to the “abundance-based representative”. (B) plot of all $H'$ values of the 48 biophysical variables * globe/regions combinations (small gray dots), and averaged $H'$ values for the globe and the 7 regions (large colored dots); red labels and arrows depict the strength of both motivations.