Do Species-poor Forests Fool Conservation Policies? Assessing the Role of Forests, Biodiversity and Income in Global Conservation Efforts

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Abstract

This paper exploits World Development Indicators and IUCN Red-List data to empirically assess the socio-economic and environmental drivers of conservation efforts. In addition to spatial spillovers, our results firstly indicate that forest cover, income level along with good political institutions positively drive protected areas (PAs), while human population growth conflicts with nature conservation efforts. Secondly, indicators of biodiversity (species richness and extinction risk) are found to be statistically neutral to PAs share, suggesting that species-rich countries are not predominantly the ones sheltering the largest PAs share. As species-poor forests matter as well, in addition to ecosystem centered approaches, our results encourage conservation practitioners to further account for species richness and extinction risks in establishing and managing PAs.

Keywords: Ecosystem, Conservation, Economic development, Spatial Analysis.

1. Introduction

Existing works in ecological modernization theory predict large demands for environmental quality in high-income countries, suggesting that conservation efforts are likely development level driven (Mol and Spaargaren, 1993; Mol, 2000). Hence, Protected Areas (PAs), known as the core instrument of nature conservation policies, might be income level dependent. Such an observation raises questions on factors enhancing conservation efforts and whether income-level relevant conservation actions will help achieve global ecosystem preservation goals. Addressing these questions, the present paper proposes to assess the socio-economic and environmental factors influencing conservation policies worldwide, using the share of PAs in surface area as a proxy for conservation efforts.

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First, on their importance, PAs are of main hope for meeting the ambitious global conservation targets (Le Saout et al., 2013). Furthermore, being the core-unit of nature conservation policies, PAs will be of major importance in facing challenges such as water security, human health and climate change (Chape et al., 2005; Hartley et al.,2007; Joppa and Pfaff, 2011). Largely, the existing studies on the importance of PAs definitely agrees on their role in slowing deforestation and protecting endemic species (Naughton-Treves et al., 2005; Sims and Alix-Garcia, 2017; Bruner et al., 2001). Second, the PAs downgrading and downsizing literature (Symes et al., 2016; Pack et al., 2016; Cook et al., 2017) discusses the causes and consequences of PAs loss to argue that the latter weakens PAs' performance in ecosystem preservation. However, considering topics related to PAs' environmental drivers, the role of development level as well as efficiency in their geographical distribution, surprisingly very few research papers can be identified. Therefore, in addition to globally assessing environmental and socio-economic drivers of PAs, This study aims at questioning efficiency in PAs' geographical distribution by distinguishing low- and high-income countries as well as geographical blocks.

By comparing mean PAs share in surface area in low- and high-income countries (Figure 1), it appears that larger PAs are sheltered by high-income countries. On the contrary, considering a proxy for species richness (species density), fairly larger shares are observed in low-income countries.

[Figure 1 near here]

Dissociating tropical from temperate climate countries, comparable PAs share in tropical and non-tropical areas are observable, whereas much larger species richness are noticed in tropical areas (Figure 2). Since biological species mostly lie in tropical countries, which predominantly are low-income countries associated with relatively high deforestation and species extinction rate (Asafu-Adjaye, 2003; Polasky et al., 2005), significantly larger PAs shares are also expected to be located in tropical countries. The charts analysis suggests a different perspective and this study aims to assess the reasons species-rich tropical areas appear to be poorly covered by PAs.

[Figure 2 near here]

Assessing the role of environmental and socio-economic factors in nature conservation efforts, this paper uses as indicator of the latter the share of PAs in surface area, without any distinction between management categories. We are aware that proceeding this way is questionable, as it treats PAs with different management categories equally.[1] Nevertheless, contrary to PAs effectiveness analyses, our study aiming at globally assessing the determinants of protected areas, such an approach appears to be reasonable. Moreover, considering total PAs share in surface area serves as a good proxy for country-level relative demand for nature conservation.

We believe the added value of this study is twofold. First, as PAs management requires huge funds, our analysis considering income level helps test whether development level significantly affects global ecosystem conservation efforts. Second, with regard to the well-known ecosystem-centered and species-centered debate in conservation, our analysis helps assess the role of environmental determinants such as forest cover, species richness and extinction risk in influencing PAs.

Section 2 overviews the related literature. Sections 3 and 4 respectively present the data and propose an insight into the PAs-income and PAs-forest cover nexuses, among others. The econometric specification is briefly discussed in Section 5. Our results are reported and discussed in Section 6 and 7. In Section 8, we conclude the study.

2. Related literature

The existing literature on conservation policies, among others, discussed species versus ecosystem centered approaches (Betts et al., 2014; Santos-Filho et al., 2016), proactive versus reactive approaches in biodiversity management (Heller and Zavaleta, 2009; Drechsler et al., 2011) and questions the effects of PAs on local communities (Sims, 2010; Richardson et al. 2012). Furthermore, it is characterized by PAs effectiveness analysis and also assesses the drivers of PAs withdrawal. The present paper dealing with factors influencing conservation efforts, this literature overview focuses on effectiveness and PAs withdrawal analyses.

Regarding PAs effectiveness, the literature is animated by Bruner et al. (2001), Naughton-Treves et al. (2005), Mas (2005), Andam et al. (2008), Butchart et al. (2012), Barnes et al (2015), Sims and Alix-Garcia (2017), to cite few. Addressing deforestation, Naughton-Treves et al. (2005) surveyed the expansion of PAs to conclude relatively low deforestation rates are definitely observed within PAs. On the same topic, the empirical results by Joppa and Pfaff (2010) are supported by the recent findings by Sims and Alix-Garcia (2017) and Blankespoor et al. (2017). Joppa and Pfaff (2010) using data on 147 countries concluded that PAs reduce the clearing of natural forest land.

[1] These categories are: "Strict Nature Reserve", "Wilderness Area", "National Park", "Habitat/Species Management Area", "Protected Landscape" and "Protected area with sustainable use of natural resources".

Similarly, exploiting data on 64 countries, Blankespoor et al. (2017) find results strengthening the effectiveness of parks in slowing deforestation. Andam et al. (2008) reach alike conclusions in Costa Rica. In the Indonesian case, Gaveau et al. (2009) stress that relatively low deforestation rates are observed in PAs. Inter-alia, Adeney et al. (2009) and Soares-Filho et al. (2010) in the case of the Brazilian Amazon and Bray et al (2008), Songer et al. (2009) and Southworth et al. (2004) respectively in the case of Guatemala, Myanmar and Honduras show that establishing PAs reduces human impacts on existing forests. In Mexico, Sims and Alix-Garcia (2017) comparing PAs and Payments for Ecosystem Services (PES) argue that both policies help fight forests clearing.[2]

Considering biodiversity, Bruner et al. (2001) assessed 93 PAs in 22 tropical countries to argue that even in situations of underfunding and of significant local land-use pressure, tropical PAs effectively protect ecosystem and species richness within their borders. Targeting specific groups of species, Butchart et al. (2012) and Barnes et al. (2015) find results suggesting that PAs reduce extinction risk. In addition, Barnes et al. (2015) point out the existence of very important sites poorly covered by PAs. Nevertheless, birds in PAs are not significantly better protected than those outside, as long as there are forests and ecosystem outside PAs. Recent contributions by Watson et al. (2016), Hiley et al. (2016) and Polak et al. (2016) among others lead to comparable results. A further aspect of this literature led by Badalamenti et al. (2000), Kwaw et al. (2010), Sims (2010), Richardson et al. (2012) and Canavire-Bacarreza and Hanauer (2013) focuses on the effects of PAs on local communities. Its conclusions though remain somewhat controversial.

A recent aspect of the literature has been investigating PAs downgrading, downsizing, and degazettement (PADDD), the aim being to assess the patterns and analyse the drivers and consequences of PAs withdrawal. Thereby, works by Mascia et al. (2014), Symes et al. (2016), Pack et al. (2016) and Cook et al. (2017), to cite few, identify factors such as industrial-scale commodity production and resources extraction, energy production, land claims and human settlements as being the main causes of PADDD. Besides the effectiveness analysis, this literature provides evidence of PAs losses, which likely undermine the performances of PAs. Overall, researchers agree on the role of PAs in slowing deforestation and in protecting endemic species, at least within PAs. However, empirical economics works questioning the role of income level and environmental factors in driving PAs appear to be less regarded, motivating this paper.

[2] Blankespoor et al. (2017) propose an exhaustive review on such country-level analyses.

3. The data

Similar to the large existing empirical literature on environmental issues, where environmental indicators are explained by per capita GDP and other potential determinants (e.g. Dietz and Adger, 2003; Richardson et al., 2012), this paper explains PAs share in surface area by income per capita, forest cover, proxies for species richness and extinction risk. To this end, our dataset includes series on forest cover, number of animal and plant species (total species identified and count of threatened) along with economic and social indicators such as income per capita, population dynamics among others. Due to few variabilities in PAs shares and series on biological species over time, in addition to missing values, the dataset is restricted to 156 countries observed in 2012. The data are mostly extracted from the World Development Indicators (WDI) except the counts of biological species, which are drawn from the IUCN Red-List of threatened species (category summary of country totals for animal and plants).

3.1. Descriptive statistics

Conservation efforts. As proxy for countries' efforts of conservation, we consider the share of terrestrial PAs in total land area.[3] The latter being "any site designated by countries under legislation primarily aiming at nature conservation" (EEA, 2012), disregarding management categories for the whole sample still reflects ecosystems maintenance measures taken by countries.

Environmental factors: PAs aiming at long-run nature preservation, some of their potential environmental determinants are forest cover and biodiversity indicators. Forests cover is the share of land under natural or planted stands of trees of at least 5 meters in situ (WDI, 2014). Regarding biodiversity indicators, we mainly use a proxy for extinction risk and species richness (species density). Extinction risk is computed as the share of threatened animal and plants species in total species identified. Our proxy for species richness somewhat follows the species-area relationship discussed in Dietz and Adger (2003) and Mills and Waite (2009). Thereby, we simply divided the total number of animal and plant species identified by surface area.

Socio-economic factors. Drawing upon existing works, this study considers socio-economic characteristics such as GDP per capita, population dynamics (population density, and total and rural population growth), agricultural land and forest rents. Regarding the influence of income level,

[3] It is to recall regarding European countries that the data include Natura 2000 network of PAs.

on one hand, Mascia et al. (2014) and Symes et al. (2016) discussed the role of poverty in PAs withdrawal. On the other hand, the ecological modernization and ecologically unequal exchange theories (Mol and Spaargaren, 1993; Mol, 2000) predict large demand for conservation in high income level, suggesting that PAs share is income level dependent. Concerning population dynamics, McDonald et al. (2008) and Songer et al. (2009) argue that increasing population reduces distance of cities to natural reserves and Symes et al. (2016) conclude that the latter leads to PAs loss. As agricultural expansion and forests resources exploitation are proven to be driving habitat loss (Koh and Ghazoul, 2010), we account for this using the share of agricultural land in total land area and forest rents in GDP.

Finally, we control for educational level and institutional characteristics as done in the existing literature (e.g. Nguyen-Van, 2003; Bhattarai and Hammig, 2001), by exploiting the mean years of schooling and index of control for corruption. The latter Worldwide Governance Indicator (WGI) captures the "extent to which public power is exercised for private gain" (The World Bank Group). Descriptive Statistics of the variables mentioned above are reported in Table 1. Thereby, it appears that on average, PAs and forests respectively cover circa 16% and 31,4% of national territories. However, it is to signal that countries such as Djibouti and Libya have less than 0.15% of their national territories as PAs, while 0.0% of forest shares are observed in Qatar and Oman. Overall, the data show for our sample of 156 countries a mean species richness of circa 37 species per 1000 square kilometre for a mean extinction risk of circa 11.82%.

[Table 1 near here]

3.2. An Insight into the data on forest and PAs cover

As the descriptive statistics do not provide sufficient information regarding the geographical distribution of forest share and most importantly of PAs, we propose maps reflecting countries share of PAs and forest cover (Figure A1, in Appendix). Observing the maps, we notice that countries with relatively large PAs share also seem to show high shares of forest cover. Focusing on Sub-Saharan Africa, South America and Western Europe on both maps, relatively dark colourings are observed in the same areas. Reciprocally, in North America, Russia and Asia both maps display relatively lightened colourings. Moreover, compared to tropical countries, lower shares of PAs and forest cover are observed in countries located far from the equator. Although very insightful, these interpretations should be carefully considered, since a map analysis seems considerably short in quantitatively addressing the role of forest cover in driving conservation policies.

4. The PAs-income, forest and species richness nexuses

Before any parametric analysis of the determinants of PAs, we propose a non-parametric insight into the PAs-income, PAs-forest, PAs-species richness and PAs-institutions nexuses. Thereby, we rely on the Nadayara-Watson estimator for models with a single explanatory variable.

The regression lines (Figure 3) indicate that income and forest cover are positively linked to PAs share, while biological species richness shows a seemingly non-significant effect. Regarding the latter relationship, no clear upward or downward trend can be claimed as the confidence intervals are quite large. Finally, political institutions (control for corruption) show an upward trend to PAs share, suggesting that good political institutions might be enhancing conservation efforts.

[Figure 3 near here]

5. Econometric model

PAs being geographical spaces dedicated to nature conservation goals, countries located in the same geographical areas likely show similar patterns in PAs share: Spatial spillovers. Therefore, we hypothesize the existence of spatial dependence in PAs share and consider an econometric specification that accounts for geographical spillovers using a geography-based connectivity weighting system. Countries involved in our analysis and details about the geographical links employed in building the weighting matrix, $W_{n\times n}$ are reported in Figures A2 and A3.

As we believe PAs to be globally subject to spatial dependence, the assumptions underlying the least square estimator are likely not fulfilled. Therefore, relating PAs share to potential drivers, the results of a standard linear model may be flawed. Econometric texts (Anselin 2013; Arbia, 2014; LeSage and Pace, 2009) argue for exploiting spatial inference techniques, the latter considering geographical links between observations.

Starting from the following standard regression model $y = X\beta + \varepsilon$ with $\varepsilon|X \sim iid(0, \sigma^2 I)$, the corresponding spatial regression model in case of spatial dependence in the dependent variable (y), in the vector of explanatory variables (X) and in the residuals (ε) is:

$$y = \rho W y + W X \beta_w + X\beta + \varepsilon \qquad \text{with } |\rho| < 1 \tag{1}$$

$$\varepsilon = \delta W \varepsilon + \mu \quad \text{with } \mu|X \sim iid(0, \sigma_\mu^2 I) \text{ and } |\delta| < 1 \tag{2}$$

where ρ, β_w, β and δ are the model's parameters. This general form subsumes several models depending on whether the parameters of the spatial terms, ρ, β_w and δ, equal 0 or not. Thus, in absence of residuals spatial autocorrelation ($H_0 : \hat{\delta} = 0$) and when Wald tests indicate that including the spatial lag of the regressors, WX, does not statistically improve the quality of the regression ($H_0 : \hat{\beta}_w = 0$), the model is finally restricted to:

$$y = \rho W y + X\beta + \varepsilon, \quad \text{assuming} \quad \varepsilon | X \sim iid(0, \sigma^2 I) \tag{3}$$

The regression model (3) is the final specification this empirical study uses in analysing the environmental and socio-economic drivers of PAs.[4] Econometric literature suggests Maximum Likelihood (ML) procedures (see Anselin, 2013; LeSage and Pace, 2009; Bivand et al., 2015) which help estimate the parameters of (3).

6. Estimation results

6.1. Specification tests: Evidence of spatial dependence in PAs

Before estimating the parameters, we test for spatial dependence in PAs share as well as in the residuals, using $W_{n \times n}$ by exploiting Moran-I tests under randomization and Monte-Carlo permutation tests. The tests results (Table 2) support our assumption regarding the presence of geographical spillovers in PAs, justifying the specification of the spatial regression model (3). Based on these first results, the spatial lag of PAs, Wy, is introduced into the model.

Next, four different models (Model 1-4) are estimated using ML techniques, whose respective residuals are exploited in testing for residuals spatial autocorrelation ($H_0 : \hat{\delta} = 0$). Observing the latter test results, we fail to reject H_0, suggesting no residuals spatial autocorrelation. Finally, we test whether the spatial lag of the regressors, WX, should be introduced into the model by exploiting Wald tests, which actually compares models without WX to augmented ones ($H_0 : \hat{\beta}_w = 0$). The results at 1% and 5% significance-levels indicate that introducing WX does not significantly improve the quality of the model.[5] Overall, the preliminary tests recommend models including only the spatial lag of PAs, Wy, thus equation (3).

6.2. Estimating spatial lag models of PAs

Addressing endogeneity. Next to specification tests, the parameters of (3) are estimated addressing endogeneity. Indeed, the presence among regressors of variables such as per capita GDP, forest rents, agricultural land and forest cover as well as biodiversity indicators raises endogeneity issues.

[4]This final form of the regression model is actually suggested by specification tests. See Table 2

[5]Still, we report in Appendix (Table A1) the results of estimating the SLM with WX.

Regarding production activities for instance, the literature has proven conservation actions to be income level dependent (Mol and Spaargaren, 1993; Mol, 2000). Reversely, as production process exploits ecosystem services and natural resources, per capita GDP, forest rents and agricultural land can be explained by PAs share. Hence, there appears to be inverse causality between economic and environmental indicators. Similar observations hold for forest cover and biodiversity. Precisely, since PAs help reduce forest clearing and protect species, observed forest cover, species richness and extinction risk can also be expressed as depending on conservation efforts.

To address these endogeneity issues, we rely on instrumental variables technique, using as instrument for each of the variable listed above its one year-lag. In doing so, the predicted values of the first stage regressions are next used in estimating the parameters of the second stage model.

Results of estimation. The outcomes of estimating the spatial lag model of PAs and corresponding average direct impacts are reported in Table 2. First, the results support the existence of positive spatial spillovers in PAs share. The weighting system being geography-based, a positive $\hat{\rho}$ suggests that increases of PAs share in the neighbouring countries enhance conservation policies in a considered country, all other things being equal. In addition to geographical spillovers, the results fairly endorse claims regarding the non-randomness of establishing PAs. Comparing information criteria, it is to signal that the following results interpretation is essentially based on Model 4.

[Table 2 near here]

As the ecological modernization theory predicts the extent of conservation policy to increase with development level, income per capita is expected to be encouraging conservation efforts. As predicted, per capita GDP positively drives PAs, implying that the higher income level, the larger nature preservation efforts (PAs share in surface area). The same result is noted in Dietz and Adger (2003). Concerning forest cover, our results show that relatively large PAs shares are observed in countries with high forest cover, since decelerating deforestation is among the objectives of conservation policies. This means that implementing PAs, conservationists specifically target locations with large natural habitats for animal and plants species, Forests. Similar conclusions appear in the PAs effectiveness literature and also in Brockett and Gottfried (2002) and Sierra and Russman (2006) in the case of PES.

Controlling for geographical location, we introduce a proxy for climate zone into the regression model. Climate zone, measured by the distance of the capital city from Equator, shows a significant negative effect on PAs share. This indicates that compared to the Poles, larger natural reserves are observed in countries located close to the Equator. Reciprocally, fewer terrestrial PAs are located far from the equator. Biological species mostly lying in tropical rainforests, such a result seems not surprising, as conservation efforts aim not only to reduce deforestation but also species loss.

Regarding the indicators of biodiversity, namely species richness and extinction risk, less conclusive outcomes are observed. Both variables show no significant effects on PAs share, implying that biological species density and the risk of extinction are not genuinely accounted for, when it comes to establish PAs. The latter results remain unchanged, when further factors are controlled for, suggesting that conservation efforts are mainly income and forest cover driven. How does forest cover drives PAs, whereas species density does not? The "empty forests" hypothesis (Redford, 1992; Wilkie et al., 2011; Antunes et al., 2016) provides some reasonable explanations to our results. Concretely, the latter argues that as large species have already gone ecologically extinct in several forests, when implementing conservation policies "we must not let a forest full of trees fool us" into believing in its biological species richness (Redford, 1992). Nevertheless, focusing on forests when establishing PAs seems practical, as naturalness and ecosystem services of forests matter as well.

Demographic pressure, captured by population density and population growth, shows negative links to PAs, denoting possible conflicts over habitat between human population and natural reserves. The latter result suggests the existence of an unfriendly cohabitation between nature conservation efforts and human population growth. Similar results on the consequences of human population are discussed by McDonald et al. (2008) and Songer et al. (2009). Specifically, shrinking distances of cities to natural reserve, population growth and cities enlargement lead to withdrawal of PAs. Moreover, by controlling for rural population, we find results indicating that rural population growth is not globally to blame for conflicting with conservation actions. Hence, the adverse effects of population on conservation efforts are likely global level effects rather than being only imputed to rural populations.

Agricultural land and forest rents show no significant effects on PAs size. Controlling for education and political institutions, by using the mean years of schooling and control for corruption index, our results show a positive role of political institutions in empowering nature conservation measures. The latter corroborates the existing literature suggesting that improving political institutions may help strengthen environmental policies and reach nature conservation goals (Clements et al., 2010). Overall, this regression analysis helps identify forest cover as the main environmental driver of PAs share, since indicators of biodiversity are found to be neutral. In the upcoming section, we question the robustness of our results and propose a regional analysis.

7. Robustness and heterogeneity analysis

7.1. Robustness check

The main criticism of spatial analyses being whether the weighting system suits the actual scale of the geographical interactions, we check our results for robustness by employing two different weighting matrices, built using the k-nearest neighbours principle considering $k = 1$ and $k = 2$. The latter are used to test for spatial dependence in PAs, following the same procedures as above. The test results using both weighting systems show a significant parameter, supporting the presence of spatial dependence in PAs (Table A2).

The data remaining unchanged, using different weighting systems should not grossly affect the parameters, but only the amplitude of the spatial effects. The results presented in Table A3 broadly support our findings regarding the role of income level, forest and good political institutions in positively driving conservation efforts. This robustness analysis also indicates that species richness and extinction risk do not significantly drive PAs, likely suggesting the lack of systematic targeting toward biological species richness and extinction risks when establishing PAs. Consequently, countries with the highest animal and plant species richness coupled with the highest extinction risk are not predominantly those sheltering the largest PAs, regardless of management categories. Considering population dynamics, their conflicting links to PAs remain significant. Globally, our first discussions hold, as this robustness analysis leads to very comparable results.

7.2. Regional analysis

Globally assessing the determinants of PAs likely hides some regional disparities. To address that, we propose heterogeneity analyses based on income levels and regional blocks.[6] Thereby, we distinguish low- and high-income countries and consider the following three regional blocks: Africa, South & North America and Eurasia. The latter geographical blocks respectively include 46, 28 and 82 countries. Additionally, we address endogeneity by employing instrumental variables method as above, which amounts to introducing the fitted-values of the first stage regressions into the second stage model. The results of this heterogeneity analysis are reported in Table 3.

[6] To classify countries according to income level, we use the sample median of lnGDP per capita.

Income level. Per capita GDP has significant effects on PAs share only in high-income countries, supporting the increasing demand for environmental quality with development level hypothesis. Reciprocally, forest cover significantly drives conservation efforts only in low-income countries. Climate zone shows comparable results, indicating that independently of income level larger PAs shares are observed in countries close to the Equator. The indicator of extinction risk has no significant effects, while even relatively fewer PAs shares are identified in developing countries characterized by high species density, providing statistical supports to Figure 1. Finally, this income level analysis shows that good political institutions strengthen nature preservation policies in low-income countries.

Regional blocks. Per capita GDP significantly drives conservation policies only in Eurasia (mostly high-income countries), while it appears to be neutral in Africa and America. The latter outcomes also strengthen observations based on Figure 1, indicating that relatively large PAs share are located in high-income countries. Contrary to income, a positive role of forests in driving PAs in Africa seems predictable. Being mostly low-income countries, comparatively low demands for nature conservation could be theoretically foreseen in African countries. Therefore, forest cover might be the main drivers of PAs in Africa. In America however, countries with the largest forest share in surface area seem to shelter relatively fewer PAs along with conflicts between natural parks and land devoted to agricultural production. This is, increases in agricultural land lead to PAs loss in America, underlining a possible competition between agricultural production and conservation efforts. Political institutions encourage PAs establishing in Africa and Eurasia.

[Table 3 near here]

Overall, this robustness analysis supports the discussions in Section 6, highlighting the role of income and forest cover in driving nature conservation efforts. Additionally, we find that income is the main PAs driver in high-income countries (Eurasia), while forest cover significantly drives PAs in low-income countries (Africa). Moreover, PAs share appears to be neutral to biological species richness and extinction risks in both high and low-income countries. In America, there appears to be conflicts between land devoted to agricultural production and natural reserves.

8. Concluding Remarks

Conservation practitioners acknowledge PAs as the main instrument of conservation policies and the existing literature discusses the effectiveness of PAs in decelerating deforestation and protecting endemic species. Moreover, the PAs downgrading, downsizing, and degazettement (PADDD) literature points out factors driving PAs loss. However, questions regarding global efficiency of PAs in covering forests and species hotspots appear much less regarded. As the ecological modernization theory predicts high demands for environmental quality, thus large conservation efforts in high-income countries, large PAs shares are expected to be located in high-income countries, where relatively low species richness and extinction risks are actually observed. Therefore, besides PAs effectiveness and PADDD analyses, this paper proposes to assess the environmental and socio-economic drivers of conservation efforts worldwide.

To address factors influencing conservation efforts (measured by the share of PAs in surface areas), this paper exploits spatial econometrics techniques to analyse data drawn from the World Development Indicator (WDI) and UICN Red-List. First, our results support the presence of spatial spillovers in PAs share, indicating that conservation efforts or increases in PAs share in the neighbouring countries positively affect PAs sheltered by a considered country. Second, per capita GDP and good political institutions are found to be driving PAs, while population growth globally conflicts with conservation efforts. These results suggest that high-income countries, which also show relatively good political institutions allocate funds and devote larger shares of their surface area to nature conservation goals. In low-income countries however, low demands for environmental quality and weak funding capacities do not fundamentally promote nature conservation actions. Regarding environmental indicators, while the proxies for species richness and extinction risk are neutral, forest cover positively drives PAs. This implies that forests are of specific interest, when establishing natural reserves, since they serve as natural habitats for biological species.

Considering geographical blocks (Africa, America and Eurasia) and dissociating low- from high-income countries reveals some disparities with regard to the role of income and forest in driving conservation efforts. In brief, income level primarily drives PAs only in high-income countries (Eurasia), whereas in low-income countries (Africa) forest cover does. It remains questionable whether forests and income driven conservation policies will help meet global biodiversity conservation targets. In case of species-poor forests, forest cover is likely to drive conservation policies, whereas species richness would not.

Finally, even when species poor, providing a number of ecosystem services, forests and their naturalness matter as well. Therefore, in addition to ecosystem centered approaches, our study identifying forests as main environmental drivers of conservation efforts urges practitioners to further focus on species hotspots and endemic species, when implementing conservation policies.

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Figures and Tables

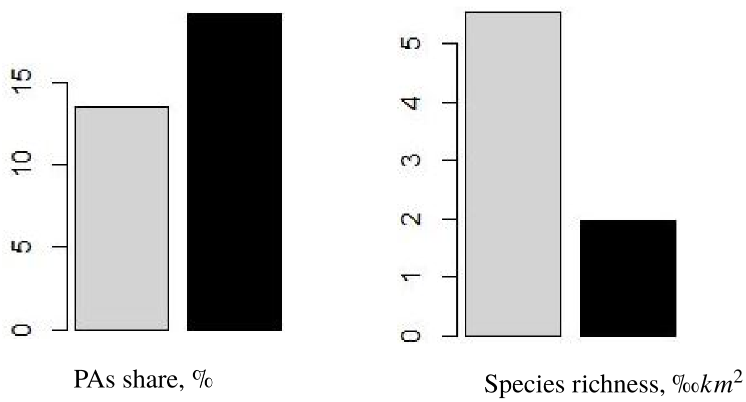


Figure 1: Mean PAs share in surface area and species richness

High-income countries

Low-income countries

Notes: Mean PAs share in surface area and species richness (animal and plant species density) for a sample of 156 high- and low-income countries. Sample median of lnGDP per capita is used to identified low- and high-income countries. More details on the data in Descriptive Statistics.

Source: The author.

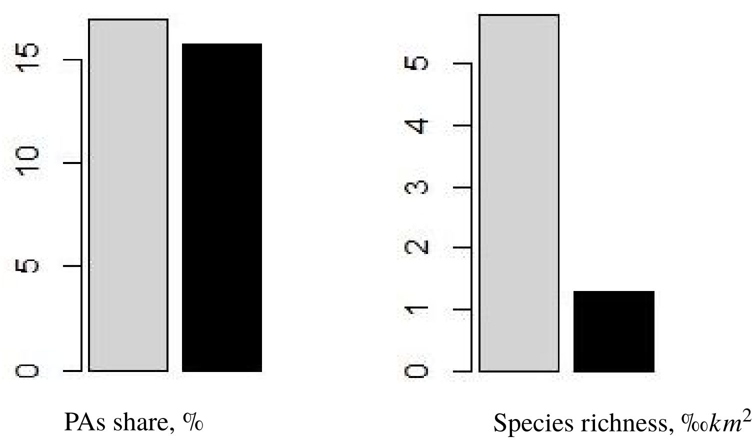


Figure 2: Mean PAs share in surface area and species richness

Temperate countries

Tropical countries

Notes: Mean PAs share and species richness (species density) for a sample of 156 countries. Areas between latitude ±30° are considered as being (sub-) tropical zones. More details on the data in Descriptive Statistics.

Source: The author.

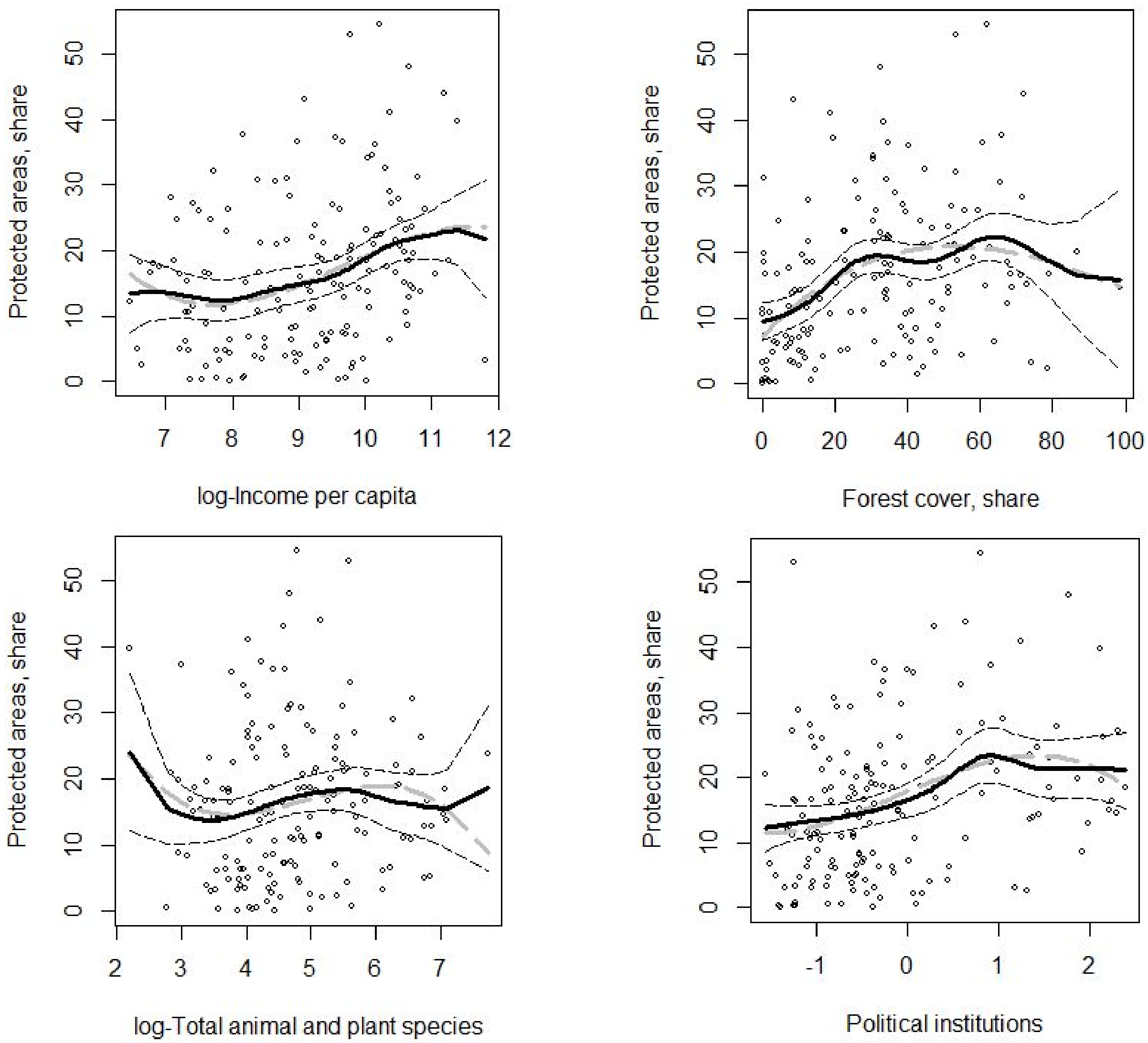


Figure 3: Kernel regression-lines with confidence intervals. The grey line corresponds to a quadratic model.

Table 1: Descriptive statistics

Variables	Units	Mean	S.D.	Min	Max
Terrestrial PAs	% area	16.348	11.594	.080	54.508
Forest area	% area	31.413	22.729	0	98.355
LnGDP per capita	$, ppp	9.108	1.229	6.462	11.798
Species richness	$10^3/km^2$	37.469	252.236	.106	3144.966
Extinction risk	%	11.820	10.273	0.283	69.517
Forest rents	% GDP	2.764	5.361	0	31.278
Agricultural land	% area	41.246	21.599	0.469	81.305
Mean years of schooling	years	7.999	3.081	1.300	12.900
Population growth	%	1.489	1.393	-1.691	9.932
Rural population growth	%	0.412	1.858	-7.967	7.799
Population density	$10^3/km^2$	0.108	0.139	0.002	1.193
Control for corruption	Index	-0.138	1.001	-1.561	2.391

Notes: The sample includes 156 countries observed in 2012. In Appendix, a list of countries.

Table 2: Results of estimating SLM of PAs and average direct impacts

Covariates, X	Model 1	Model 2	Model 3	Model 4
Spatial effects in PAs, $\hat{\rho}$	.239***(.093)	.221**(.093)	.244***(.091)	.202**(.091)
Intercept	−12.405** (6.161)	−12.721* (7.584)	−14.194* (8.379)	−4.149 (12.929)
LnGDP per capita	2.212***(.684)	3.169***(.899)	3.799***(.949)	2.889**(1.233)
Forest area	.146***(.036)	.126***(.038)	.098**(.041)	.107**(.047)
Climate zone		−.114* (.065)	−.173** (.077)	−.246***(.081)
Extinction risk		−42.952 (37.0)	−41.80 (36.772)	−43.782 (35.992)
Species richness		18.873 (33.0)	23.612 (33.222)	11.0 (32.812)
Population density			−.004 (.006)	−.005 (.006)
Population growth			−1.714* (.892)	−1.852** (.928)
Rural population growth			1.218** (.610)	1.514** (.606)
Agricultural land				.047 (.045)
Forest rent				−.079 (.204)
Mean year of education				.039 (.254)
Institution				3.188***(1.175)
Number of obs.	156	156	156	156
Log likelihood	-583.908	-581.521	-578.696	-574.598
AIC	1182.5	1182.7	1184.4	1181.9
Average direct impacts	(1)	(2)	(3)	(4)
LnGDP per capita	2.245***(.696)	3.210***(.887)	3.860***(.945)	2.920**(1.264)
Forest area	.148***(.037)	.128***(.037)	.099***(.042)	.108***(.049)
Climate zone		−.115** (.064)	−.175**(.076)	−.248***(.083)
Extinction risk		−42.509 (37.471)	−42.47 (37.343)	−44.251 (36.334)
Species richness		18.118 (34.02)	23.99 (34.204)	11.12 (33.664)
Population density			−.004 (.006)	−.005 (.006)
Population growth			−1.714* (.898)	−1.530* (.962)
Rural population growth			1.237* (.642)	1.514***(.634)
Agricultural land				.048 (.049)
Forest rent				−.081 (.197)
Mean year of education				.039 (.255)
Institution				3.222***(1.172)

	a. Tests for presence of spatial autocorrelation in PAs			
	Global Moran-I test under random.		Monte-Carlo permutation test	
	Test-stat.	0.232	Test-stat.	0.233
	p-value	2.853e-05	p-value	0.001

	b. Test for residuals spatial autocorrelation			
Moran test	(1)	(2)	(3)	(4)
Moran-I	.007	.004	.016	.022
p-value	.407	.427	.355	.313

	c. Test comparing models without and with WX			
Wald test	(1)	(2)	(3)	(4)
L. ratio	2.876	2.901	13.741	19.847
p-value	.237	.715	.088	.070

Notes: Dependent variable is the share of PAs. In brackets are asymptotic standard errors. We use the one-year lag of the series on GDP per cap., forest rents, agricultural land, forest area, species richness and extinction risk as instruments. "***", "**" and "*" respectively indicate significance at 1%, 5% and 10% levels. In *b* and *c* results of tests performed on the residuals of the corresponding model 1-4 and Wald tests. See Table A2 for the augmented Models 1-4.

Table 3: Results of robust linear models of PAs

	Income level		Regional blocks		
Covariates, X	Low-income	High-income	Africa	America	Eurasia
Intercept	5.076 (24.284)	-5.149^{*} (3.202)	8.003 (21.622)	9.404 (10.099)	-3.363^{*} (1.77)
LnGDP p. c.	3.137 (2.294)	7.691^{***}(3.215)	.869 (2.065)	5.260 (7.092)	5.714^{***}(1.723)
Forest area	$.154^{***}$(.062)	.102 (.070)	$.227^{***}$(.069)	$-.554^{**}$(.235)	.052 (.076)
Climate zone	$-.256^{**}$(.123)	$-.284^{**}$(.104)	−.106 (.189)	$-.803^{**}$(.344)	$-.249^{**}$(.116)
Extinction risk	−.697 (.548)	−.331 (.348)	−.164 (.529)	.122 (.623)	−.283 (.488)
Species richness	-1.942^{**}(.772)	.537(.351)	$-.242^{***}$(.093)	−.434 (.378)	.052 (.035)
Population density	−.002 (.007)	.003 (.011)	.013 (.021)	$-.065^{*}$ (.040)	−.003 (.007)
Population growth	2.702 (2.302)	-3.306^{***}(1.181)	.164 (3.309)	6.243 (5.940)	-2.440^{**} (1.193)
Rural pop. growth	−0.438 (1.532)	1.331^{**}(.656)	3.742 (2.450)	−2.054 (2.218)	1.124^{*} (.661)
Agricultural land	.015 (.066)	.093 (.060)	−.004 (.081)	$-.512^{**}$ (.211)	.106 (.071)
Forest rent	−.198 (.221)	−2.166 (2.057)	−.402 (.278)	.662 (3.514)	.238 (.345)
Mean year of edu.	.172 (.334)	2.096 (1.462)	−0.176 (.445)	−1.329 (.923)	.251 (.335)
Institution	4.342^{**} (2.515)	2.097 (1.462)	4.727^{*} (2.772)	−5.441 (4.586)	3.005^{**} (1.523)
Number of obs.	78	78	46	24	86
Adj. R-squared	.241	.295	.264	.387	.394
F-stat. (P-value)	3.045 (.00)	3.680 (.00)	2.342 (.02)	2.315 (.07)	5.505 (.00)

Notes: Dependent variable is the share of PAs in land area. Estimates are obtained using 2SLS methods. In bracket are robust (HAC) standard errors. See Table 2 for further comments.

Appendix

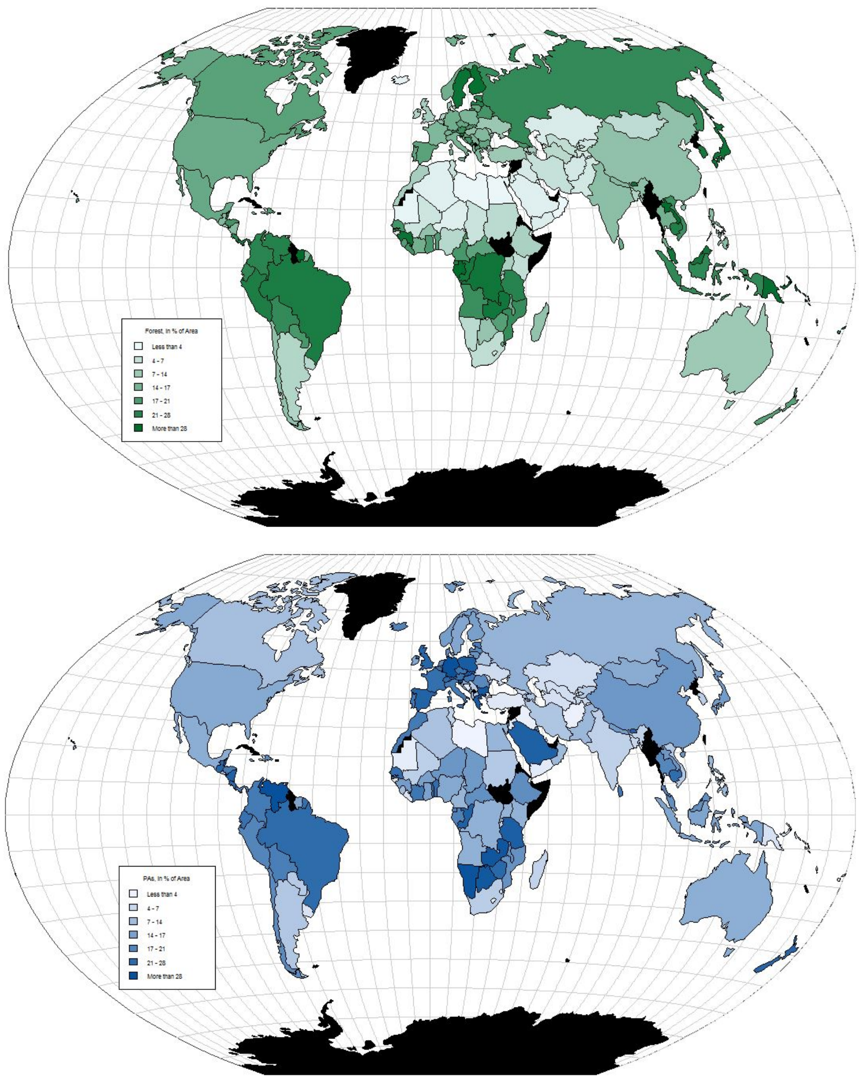
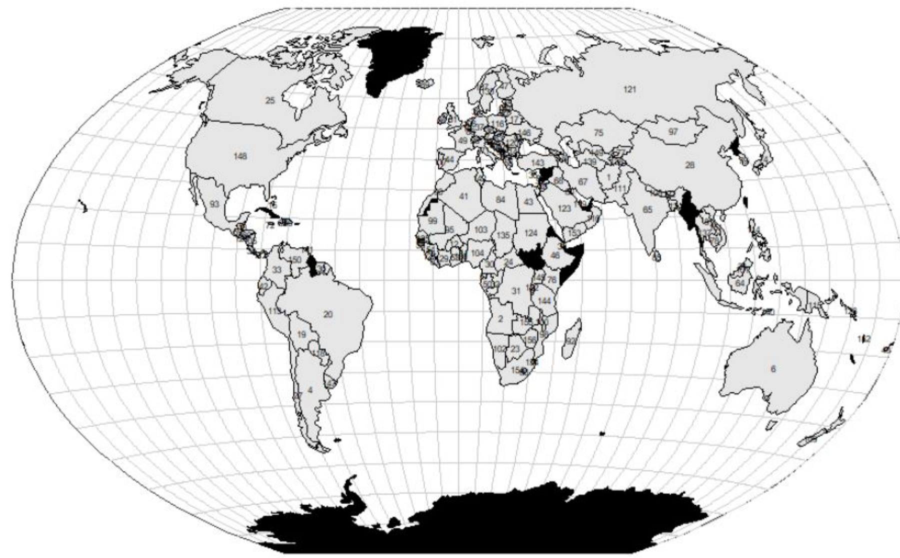


Figure A1: Map of forest cover and of PAs in % of land area



Notes: Afghanistan 1, Angola 2, Albania 3, Argentina 4, Armenia 5, Australia 6, Austria 7, Azerbaijan 8, Burundi 9, Belgium 10, Benin 11, Burkina Faso 12, Bangladesh 13, Bulgaria 14, Bahamas 15, Bosnia and Herzeg. 16, Belarus 17, Belize 18, Bolivia 19, Brazil 20, Brunei Darussalam 21, Bhutan 22, Botswana 23, Central African Republic 24, Canada 25, Switzerland 26, Chile 27, China 28, Cote d'Ivoire 29, Cameroon 30, Congo, Dem. Rep. 31, Congo, Rep. 32, Colombia 33, Costa Rica 34, Cyprus 35, Czech Republic 36, Germany 37, Djibouti 38, Denmark 39, Dominican Rep. 40, Algeria 41, Ecuador 42, Egypt, Arab Rep. 43, Spain 44, Estonia 45, Ethiopia 46, Finland 47, Fiji 48, France 49, Gabon 50, United Kingdom 51, Georgia 52, Ghana 53, Guinea-Bissau 54, Guatemala 55, Gambia, The 56, Equatorial Guinea 57, Greece 58, Guinea 59, Honduras 60, Croatia 61, Haiti 62, Hungary 63, Indonesia 64, India 65, Ireland 66, Iran, Islamic Rep. 67, Iraq 68, Iceland 69, Israel 70, Italy 71, Jamaica 72, Jordan 73, Japan 74, Kazakhsta 75, Kenya 76, Kyrgyz Republic 77, Cambodia 78, Korea, Rep. 79, Kuwait 80, Lao PDR 81, Lebanon 82, Liberia 83, Libya 84, Sri Lanka 85, Lesotho 86, Lithuania 87, Luxembourg 88, Latvia 89, Morocco 90, Moldova 91, Madagascar 92, Mexico 93, Macedonia 94, Mali 95, Montenegro 96, Mongolia 97, Mozambique 98, Mauritania 99, Malawi 100, Malaysia 101, Namibia 102, Niger 103, Nigeria 104, Nicaragua 105, Netherlands 106, Norway 107, Nepal 108, New Zealand 109, Oman 110, Pakistan 111, Panama 112, Peru 113, Philippines 114, Papua New Guinea 115, Poland 116, Portugal 117, Paraguay 118, Qatar 119, Romania 120, Russian Federation 121, Rwanda 122, Saudi Arabia 123, Sudan 124, Senegal 125, Solomon Isl. 126, Sierra Leone 127, El Salvador 128, Serbia 129, Suriname 130, Slovak Republic 131, Slovenia 132, Sweden 133, Swaziland 134, Chad 135, Togo 136, Thailand 137, Tajikistan 138, Turkmenistan 139, Timor-Leste 140, Trinidad and Tobago 141, Tunisia 142, Turkey 143, Tanzania 144, Uganda 145, Ukraine 146, Uruguay 147, United States 148, Uzbekistan 149, Venezuela 150, Vietnam 151, Vanuatu 152, Yemen, Rep. 153, South Africa 154, Zambia 155, Zimbabwe 156.

Figure A2: List of countries involved in our study

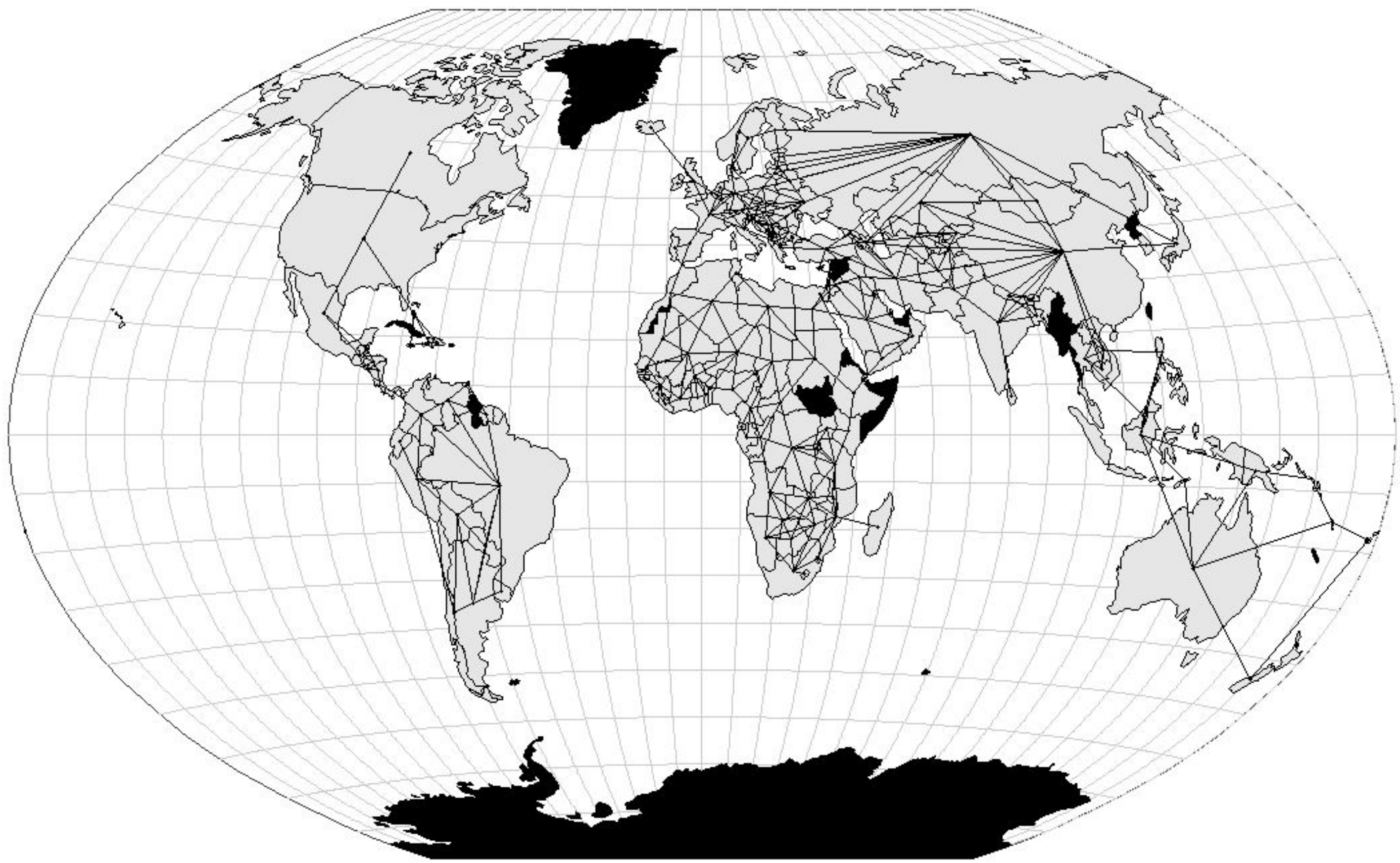


Figure A3: Borders based links used in building the connectivity matrix, $W_{(156\times156)}$

Notes: Common borders links (nearest neighbour for islands) exploited in building our main row-standardized weighting matrix characterized by 156 regions, 645 non-zero links with circa 4.135 average number of links and 2.651% non-zero weights.

Table A1: Results of estimating augmented SLM of PAs for the Wald tests

Covariates, X	Model 1	Model 2	Model 3	Model 4
Spatial effects in PAs $\hat{\rho}$	.252***(.096)	.244**(.096)	.257***(.095)	.158*(.099)
Intercept	−4.720(7.692)	−8.109 (9.769)	−14.946(12.655)	−16.176(24.15)
LnGDP per capita	3.629***(1.091)	3.809***(1.156)	4.471***(1.153)	3.297**(1.306)
Forest area	.143***(.049)	.131**(.052)	.060 (.054)	.091*(.058)
Climate zone		−.074 (.194)	−.140(.198)	−.338*(.203)
Extinction risk		2.694 (8.353)	2.314 (8.205)	−3.661 (8.008)
Species richness		.890 (3.340)	.378 (3.197)	−1.523 (3.094)
Population density			−.015**(.007)	−.014**(.007)
Population growth			−1.449 (.934)	−1.828*(.978)
Rural Population growth			1.461**(.596)	2.063***(.591)
Agricultural land				.062 (.048)
Forest rent				−.242 (.197)
Mean year of education				.059 (.247)
Institution				3.776***(1.285)
Spatial-lag.LnGDP pc	−2.283*(1.361)	−1.561 (1.652)	−1.092(1.724)	−.609 (2.202)
Spatial-lag.Forest area	.001 (.070)	.006(.072)	.077 (.078)	.147(.085)
Spatial-lag.Climate zone		−.017(.204)	−0.049 (.214)	−.002(.216)
Spatial-lag.Extinction risk		−17.479(14.152)	−26.30*(13.743)	−39.279**(13.50)
Spatial-lag.Species richness		−.007(.012)	−.008 (.011)	−.012(.011)
Spatial-lag.Population density			.039**(.012)	.035**(.012)
Spatial-lag.Pop. growth			−.632 (2.081)	−1.146 (2.097)
Spatial-lag.Rural Population gr.			.645 (1.438)	2.104 (1.467)
Spatial-lag.Agricultural land				.166*(.074)
Spatial-lag.Forest rent				−.488(.350)
Spatial-lag.Mean year of edu.				.723(.456)
Spatial-lag.Institution				−0.214(1.811)
Number of obs.	156	156	156	156
AIC criterion	1184.5	1193.2	1189.3	1181.1

Notes: Dependent variable is the share of PAs in land area. Models 1-4 have been augmented by the spatial lag of the regressors. "***" when $p < 0.01$, "**" $p < 0.05$, and "*" when $p < 0.1$. See Table 3 for further comments.

Table A2: Tests for spatial autocorrelation in PAs using different weighting systems

	Global Moran-I test under random.		Monte-Carlo permutation test	
k=1	Test statistic	.118	Test statistic	0.119
	P-value	0.00	P-value	0.001
k=2	Test statistic	.055	Test statistic	0.054
	P-value	0.001	P-value	0.007

Notes: This test's null-hypothesis is absence of spatial autocorrelation in PAs.

Table A3: Results of estimating SLM of PAs using different weighting systems

	k = 1		k = 2	
Covariates, X	Model 1	Model 4	Model 1	Model 4
Spatial effects in PAs $\hat{\rho}$	.399**(.141)	.298* (.148)	.356* (.182)	.189 (.197)
Intercept	−16.574***(6.187)	−9.369 (13.397)	−17.050*** (6.423)	−7.579 (13.772)
LnGDP per capita	2.394*** (.692)	3.196*** (1.235)	2.486*** (.692)	3.206** (1.248)
Forest area	.145*** (.036)	.117** (1.235)	.157*** (.037)	.127** (.048)
Climate zone		−.237*** (.082)		−.251*** (.048)
Extinction risk		4.667 (3.625)		−4.793 (3.662)
Species richness		7.591 (3.303)		5.955 (33.371)
Population density		−.004 (.006)		−.004 (.006)
Population growth		−1.401* (.905)		−1.621* (.959)
Rural population growth		1.429* (.611)		1.477** (.617)
Agricultural land		.0511 (.046)		.059 (.047)
Forest rent		−.065 (.206)		−.076 (.208)
Mean year of education		.024 (.256)		.049 (.259)
Institution		3.156** (1.205)		3.407*** (1.213)
Number of obs.	156	156	156	156
AIC criterion	1182.5	1181.9	1181.7	1181.1

Notes: Dependent variable is the share of PAs in land area. As proxy for institution, we use the series *control for corruption* from the WGI. In bracket are asymptotic standard errors. The models 1 & 4 have been estimated using an international panel dataset, with n=41 and T=14. $\hat{\rho}$ stands for the spatial effects in PAs. "***" when $p < 0.01$, "**" $p < 0.05$, and "*" when $p < 0.1$.