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ORIGINAL ARTICLE

A global analysis of the drivers of human pressure within protected areas at the national level

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Abstract

Global conservation efforts rely largely on effective protected areas. Recently, it was shown that one-third of the world's protected land is under intense human pressure. However, this proportion varies substantially across countries. Some countries are more successful than others in keeping their protected areas relatively free from intense human pressure. In this study, I explore the possible reasons behind this pattern. I find that countries with lower human population densities, lower percentage of agricultural land, and a larger area tend to have a lower proportion of their protected land under intense human pressure. These three factors alone account for approximately two-thirds of the variation in intense human pressure within protected areas. Other factors include the percentage of protected land under strict protection status (i.e., IUCN Categories I and II) and the current amount of funds invested in conservation at the national level. However, these factors are less important and account for little of the variation in human pressure. Moreover, there is no relationship between the levels of human pressure within protected areas and the countries' economic development status and effectiveness of national governance. These findings suggest that under the current conditions—and assuming no major reforms in national conservation policies and actions—countries with high population densities and extensive areas of agricultural land are likely to struggle to keep human pressure within protected areas at low levels, irrespective of their economic development level, national governance strength, and current investments in conservation. Worse still, future projected increases in human population densities and agricultural land will likely exacerbate the human pressure within protected areas; these increases will occur mostly in developing countries—many of which are located in biodiverse regions—making conservation in those regions more difficult. To achieve their sustainability goals, countries must take actions to address the key drivers of human pressure within protected areas.

Keywords Aichi targets · Biodiversity conservation · Convention on biological diversity · Human footprint index · Protected planet · Sustainable development goals

Introduction

We live in an era in which humans are impacting the natural environment at an unparalleled scale (Gaston et al. 2008; Corlett 2015). Human activities—which now affect most of the planet (Ellis et al. 2010; Venter et al. 2016a; Watson and Venter 2019)—result in substantial biodiversity loss (Butchart et al. 2010; Newbold et al. 2015). Protected areas represent one of the most important conservation strategies for addressing this loss (Visconti et al. 2019). According to the Strategic Plan for Biodiversity, adopted in 2010, the signatory countries to the Convention on Biological Diversity (CBD) have agreed to expand their network of protected areas to cover 17% of the planet's land area (Watson et al. 2014; Gray et al. 2016). Many countries are nearing

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that target, while several others have already exceeded it—although some are still lagging behind (Jones et al. 2018). Considering the pivotal role of protected areas in addressing biodiversity loss (Fuller et al. 2010; Watson et al. 2014; Visconti et al. 2019), it is essential we understand the factors that affect the countries' capacity to mitigate human impact within their protected areas and to conserve natural environments (Watson et al. 2014). Not surprisingly, this has been a major research topic in conservation science (Gaston et al. 2008; Geldmann et al. 2018). Most studies concur that protected areas tend to have a positive effect on biodiversity (Nagendra 2008; Joppa and Pfaff 2011; Coetzee et al. 2014; Gray et al. 2016; Geldmann et al. 2018). However, the extent to which they are able to do so varies substantially (Coetzee et al. 2014; Spracklen et al. 2015; Geldmann et al. 2019; Anderson and Mammides 2020a). Evidence suggests that many of the world's protected areas remain ineffective in conserving biodiversity and in curbing human impact (Gaston et al. 2008; Coetzee et al. 2014; Watson et al. 2014; Spracklen et al. 2015).

In fact, it was shown recently that one-third of the protected land across the planet is under intense human pressure (Jones et al. 2018). Researchers reached this conclusion by measuring the mean human footprint (Venter et al. 2016a, b) within the world's protected areas. The human footprint is a composite index of the human pressure across the globe—at a resolution of 1 km^2 (Venter et al. 2016a). It is based on eight types of human pressure, including human population densities, built-up areas, intensive agriculture, and infrastructure (Venter et al. 2016b). Although the human footprint index is based on satellite-derived data—which may not always capture finer scale anthropogenic disturbance (Peres et al. 2006; Mammides 2018)—and although it does not include other key pressures, such as pollution and invasive species, the index has been shown to be a good proxy of the human pressure on natural environments (Watson and Venter 2019). For example, increases in human footprint have been linked to increased animal extinction risk (Di Marco et al. 2018) and reduced animal movement (Tucker et al. 2018).

A glance at the list of countries and the proportion of their protected land under intense human pressure (Jones et al. 2018) reveals substantial variation. Inevitably, this variation leads to the following question: why are some countries more successful than others in keeping their protected areas relatively free from intense human pressure? It is a simple yet intriguing question that goes beyond mere academic interest. Given the fact that human pressure is still rising within many of the world's protected areas (Jones et al. 2018; Geldmann et al. 2019; Anderson and Mammides 2020a), and that it is significantly affecting biodiversity (Tucker et al. 2018; Di Marco et al. 2019; Watson and Venter 2019), the answer to this question could provide us with insights important for conservation. Once we understand better the factors associated most with the levels of human pressure within protected areas, we can shape our national and international policies accordingly to address those factors. Protected areas are imperative to the protection of the world's biodiversity and are essential for attaining the UN Sustainable Development Goals (SDGs), particularly Goals 14 and 15, which concern the sustainable use of natural resources (Dudley et al. 2017).

One could hypothesize that the proportion of protected land under intense human pressure is higher in countries within certain geographic regions. In their study, Jones et al. (2018) mention that protected areas under intense human pressure tend to be found in western Europe, southern Asia, and Africa. Other studies, too, have shown that environmental degradation varies across geographic regions (Nagendra 2008; Geldmann et al. 2019; Anderson and Mammides 2020a). Deforestation rates, for instance, tend to be higher within protected areas in Asian countries compared to countries in Latin America (Spracklen et al. 2015). Agricultural expansion rates also vary amongst regions (Geldmann et al. 2019; Anderson and Mammides 2020b).

These geographic variations are partly driven by dissimilarities in socioeconomic factors. For example, studies often cite poor national and local governance as one of the main reasons for why protected areas are sometimes ineffective in mitigating human impact (Wright et al. 2007) and conserving biodiversity (Smith et al. 2003; Smith and Walpole 2005). Countries with more effective governance should have a higher capacity to enforce national and international environmental policies (Smith et al. 2003). Therefore, they should be able to regulate better the levels of human pressure within their protected areas (Watson et al. 2014).

Besides governance, another commonly cited reason for increased human pressure within protected areas is lack of resources (Leader-Williams and Albon 1988; Bruner et al. 2001), particularly financial resources. Having adequate financial resources for conservation is important (Bruner et al. 2001; McCarthy et al. 2012; Miller et al. 2013; Waldron et al. 2013). Waldron et al. (2017) showed that higher financial investments in conservation—at the national level—can be linked to lower rates of biodiversity loss within countries. It is reasonable to hypothesize that higher conservation funding translates into lower proportions of human pressure within protected areas; this could even be the mechanism behind the reduced biodiversity loss reported by Waldron et al. 2017.

High human population densities are a major determinant of anthropogenic disturbance in natural environments (McKee et al. 2004). It is for that reason that human population densities are incorporated explicitly into the human footprint index (Venter et al. 2016b). Human population densities are also the driving force behind a range of other factors associated with anthropogenic disturbance (Luck 2007). For instance, higher human densities result in more built-up environments and more infrastructure and hence further human-induced environmental change (Cincotta et al. 2000). It is, therefore, probable that countries with higher population densities have a higher proportion of their protected land under intense human pressure. It is essential to clarify here, though, that although this reasoning may seem circular at first—i.e., to use human densities to explain the levels in human footprint, when human densities are part of the index—, in reality it is not, because here we are interested in understanding human pressure within protected areas specifically. One would expect countries—including densely populated countries—to be able to keep their protected areas mostly free from intense human pressure, especially considering the demonstrated negative impact of the human footprint on biodiversity (Di Marco et al. 2018; Tucker et al. 2018; Watson and Venter 2019).

Agricultural land expansion is also a known major driver of anthropogenic disturbance in natural environments (Brussaard et al. 2010; Rockström et al. 2017) and has been shown to affect biodiversity negatively (Brussaard et al. 2010; Karp et al. 2012)—e.g., through habitat loss and fragmentation (Ramankutty et al. 2018). Reports from global and regional assessments suggest that it is not uncommon to have large areas of agricultural land within protected areas (Geldmann et al. 2019; Anderson and Mammides 2020b), even within strictly protected nature reserves. Considering the current scale of the agricultural activities across the planet (Molotoks et al. 2018), it is probable that countries with more agricultural land have more of their protected areas under intense human pressure. It is also probable that else being equal, countries with smaller land area have a higher proportion of their protected land under intense human pressure because of increased competition for land resources (Smith et al. 2010).

Lastly, it is possible that human pressure within protected areas is linked to their type of protection status (Nelson and Chomitz 2011). There are several types of protected areas, and although in many of them human activities and use of natural resources are strictly prohibited, in others they are allowed (Dudley 2008) in an effort to minimize the social impacts on the local communities and the resulting conflicts (West and Brockington 2006; West et al. 2006; Dudley et al. 2018; Mammides 2020). The International Union for Conservation of Nature (IUCN) recognizes six categories of protected areas, which reflect a gradient of permissible human uses (Dudley 2008). For example, protected areas belonging to IUCN Categories V and VI permit multiple sustainable nonindustrial uses (Dudley 2008), which are often prohibited in strict nature reserves and national parks, i.e., IUCN Categories Ia and II (Chape et al. 2005; Leroux et al. 2010). It is possible that countries with more of their protected land under stricter status have lower proportions of protected areas under intense human pressure.

In this study, I explore the factors that influence most the levels of human pressure within the world's protected areas at the national level (Jones et al. 2018). In particular, I answer the following questions:

a. Is the proportion of protected land under intense human pressure related to the country's level of economic development, measured using its per capita gross domestic product (GDP)?
b. Do effective national governance and higher conservation spending lead to lower levels of human pressure within protected areas?
c. Do higher human population densities lead to higher levels of human pressure within protected areas?
d. Do countries with a higher percentage of agricultural land or smaller land area have a higher proportion of protected land under intense human pressure?
e. Does a higher percentage of protected land under strict protection status lead to lower levels of human pressure within protected areas?

Materials and methods

Data collection

I calculated each country's proportion of protected land under intense human pressure using the data provided by Jones et al. (2018). The data represent the percentage of protected land within each country—in terms of its total land area—under low and high human pressure (i.e., a mean human footprint value of <4 and ≥ 4, respectively). The data are based on the most recent version of the human footprint index from the year 2009 (Venter et al. 2016b). The human footprint index is a composite measure of the human impact across the planet, calculated using the following eight types of human pressure: (1) built-up areas; (2) intensively farmed crop land; (3) pasture land; (4) human population density; (5) night-time lights; (6) railways; (7) roads; (8) navigable waterways (Venter et al. 2016a; Jones et al. 2018). These eight types of human pressure are first standardized and weighted according to their relative impact (Sanderson et al. 2002; Venter et al. 2016a) and then summed to provide a cumulative score of human pressure ranging from 0–50 (Venter et al. 2016a; Jones et al. 2018).

To calculate each country's proportion of protected land under intense human pressure, I divided each country's percentage of protected land with a mean human footprint value of ≥ 4, by its total percentage of land covered by protected areas (Jones et al. 2018). For the purposes of the analysis here—and following the protocol of the Environmental

Sustainability Index (Schmiedeknecht 2013)—I excluded countries with a land area of less than 5000 km^2 ($n=17$) and I also excluded countries that had less than 3% of the area covered by protected areas ($n=15$). In total, there were 130 countries for which there were complete data for all the variables included in the analysis (the list of variables is presented below).

The data on conservation spending and government effectiveness were obtained from Waldron et al. (2013) and cover the years 2001–2008. Conservation spending represents the total amount of funds spent for conservation within each country during the above-mentioned period (Waldron et al. 2013). These were either funds coming from large international and foreign donors, such as the World Bank and the Global Environment Facility Trust Fund, or from the countries' own budgets (Waldron et al. 2013). Importantly, many of these funds concern investments in protected areas (Waldron et al. 2013) and hence are relevant to the analysis presented here, which explores the factors associated with the levels of human pressure within protected areas.

The data on national governance are essentially a measure of each country's effectiveness in "formulating and implementing policies" (Waldron et al. 2013). Admittedly, governance is a multidimensional and complicated concept and, therefore, difficult to capture with one metric (Eklund and Cabeza 2017). It is possible that the results of the analysis presented here were influenced, at least partly, by the metric chosen to measure national governance. To assess the extent to which this was the case, I ran the analysis again using the national governance metric included in the Environmental Sustainability Index (Schmiedeknecht 2013). The index was prepared jointly by institutions led by the Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network (CIESIN) of Columbia University, and is comprised of a series of metrics that aim at measuring each country's level of environmental sustainability (Schmiedeknecht 2013). Among the metrics included, one is labeled "environmental governance" and its purpose is to measure the governance effectiveness of the countries specifically regarding environmental matters. Hence, in addition to indicators such as corruption and rule of law, the metric includes indicators related also to the environment, such as memberships to IUCN organizations and Local Agenda 21 initiatives. Yet, regardless of which national governance metric was used in the analysis, the results were similar; therefore, here I present the results based on the metric compiled by Waldron et al. (2013), which was available for a few more countries (resulting in a higher sample size). The results based on the governance metric extracted from the Environmental Sustainability Index can be found in the supporting information (Table S1).

The data on the countries' human population densities, extent of agricultural land, and economic development level were obtained from the World Bank; using the "WDI" package in R, I downloaded the following three indicators, which are also available online at https://data.worldbank.org/indicator: (a) total human population size ("SP.POP.TOTL"); (b) percent of agricultural land ("AG.LND.AGRI.ZS"); and (c) gross domestic product per capita ("NY.GDP.PCAP.CD"). Following the approach of Waldron et al. (2013), I used each indicator's average value between the years 2001–2008. To calculate each country's percentage of protected land under strict protection status I used the World Database of Protected Areas (WDPA; October 2018 version) available at https://protectedplanet.net. In line with the methods of Jones et al. (2018), I classified protected areas ≥ 5 km^2 according to their IUCN category as follows: (a) strictly protected areas (Categories I and II), (b) non-strictly protected areas (Categories III–VI), and (c) areas with no IUCN category reported. Then, for each country, I estimated the percentage of protected land (in km^2) belonging to the first class; a higher percentage corresponded to more protected land under strict protection status.

Data analysis

To identify the factors that are associated most with the proportion of protected land under intense human pressure, I ran a generalized linear mixed model (with a binomial error distribution), which included the following seven variables for each country: (1) total land area (km^2); (2) human population density (inhabitants/km^2); (3) percentage of land area covered by agricultural land (%); (4) economic development level, measured using the gross domestic product (GDP) per capita (current US$/inhabitants); (5) conservation spending (million US$); (6) national governance effectiveness; and (7) percentage of protected land under strict protection status (%). I log-transformed total land area, human population density, GDP per capita, and conservation spending to meet the assumptions of linearity and homoscedasticity, i.e., constant variance (Zuur et al. 2010). Since it was possible that some of the independent variables used in the analysis were correlated with each other—leading to biased estimates (Akinwande et al. 2015)—I examined whether collinearity was an issue by calculating each variable's variance inflation factor (Akinwande et al. 2015), using the *vif* function in the "car" package (Fox and Weisberg 2011). I used the continent of each country as a random effect to account for the possibility that countries within the same geographic region have similar characteristics (Lira-Noriega and Soberón 2015). However, it accounted for zero variance, and therefore I proceeded with a simpler generalized linear model (i.e., one with no random effects).

I used information-theory (Burnham and Anderson 2002; Hegyi and Garamszegi 2011) and model averaging (Symonds and Moussalli 2011; Grueber et al. 2011) to assess the relative importance of each independent variable. Specifically, I used the "MuMin" package (Bartoń 2019) in R to average all models with a ΔAICc of less than 2. ΔAICc is the difference between the AICc value of each model and that of the best model, i.e., the one with lowest AICc value (Grueber et al. 2011). The rationale behind the model averaging approach is that models with a ΔAICc of <2 are also plausible (Burnham and Anderson 2002) and consequently contain information that should be included in the results (Burnham and Anderson 2002; Grueber et al. 2011); this is achieved by averaging the regression coefficients of the selected models. I used the full-average method—also called the zero method (Grueber et al. 2011)—because it is more appropriate for studies such as this one in which the aim of the analysis is to assess the relative importance of each independent variable (Grueber et al. 2011). For each variable, I calculated its unstandardized and standardized regression coefficients. I used the "rsq" package (Zhang 2018) in R to calculate the pseudo-R^2 value of the best model and the pseudo-R^2 value of the model which contained all the variables selected during the averaging process. For each variable in the latter model, I also calculated its partial pseudo-R^2 value (Zhang 2018) to assess its relative contribution to the overall variance explained.

Results

The median proportion of protected land under intense human pressure within each country was 0.63 (ranging from 0.03 to 1.00), showing that in most countries more than half of their protected land has been already affected by intense human pressure. The variables in the best model—i.e., the model with the lowest AICc value—explained approximately two-thirds of the variance in the proportion of protected land under intense human pressure ($R^2=0.61$). The model consisted of the following three variables: (1) human population density; (2) percentage of agricultural land; (3) total land area. Countries with lower human population densities, lower percentage of agricultural land, and a larger area had a lower proportion of their protected land under intense human pressure (Fig. 1). The highest variance inflation factor—when the full model was tested (i.e., with all seven variables)—was 4.5, suggesting no substantial collinearity (Defries et al. 2010; Akinwande et al. 2015). There were ten models with a ΔAICc of less than 2 (Table S2), showing that some of the other four factors were also related to the levels of human pressure within protected areas. Indeed, the final averaged model included all seven original variables ($R^2=0.63$; Table 1).

The relationship between conservation spending and the proportion of protected land under intense human pressure was negative (Table 1), meaning that countries that had received and spent more funds on conservation had a lower

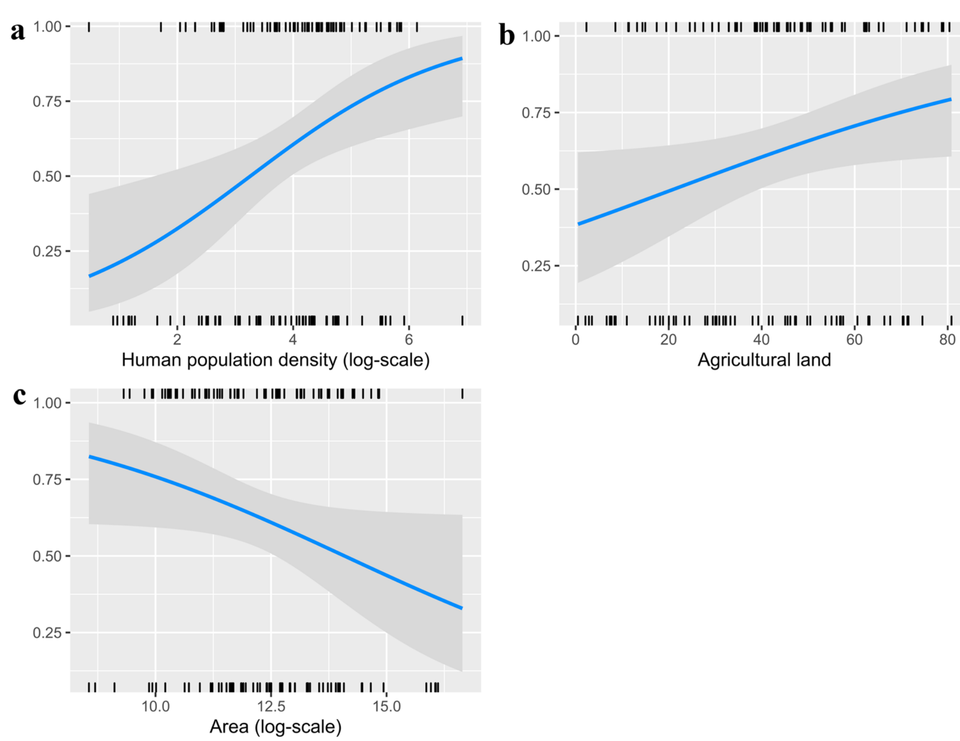

Fig. 1 Relationship between the countries' proportion of protected land under intense human pressure and **a** human population density, **b** percentage of agricultural land, and **c** total land area. The figures are based on the best model (i.e., the model with the lowest AICc value; pseudo-$R^2=0.61$)

Table 1 Results of the model-averaging process showing the factors associated most with the proportion of protected land under intense human pressure at the national level

Variable	Standardized		Unstandardized		Sum of weights	Partial pseudo-R^2
	Coefficient	Std. Error	Coefficient	Std. Error		
Population density	0.82	0.28	0.68	0.22	1.00	0.282
Agricultural land	0.41	0.22	0.02	0.01	1.00	0.163
Land area	− 0.19	0.25	− 0.13	0.17	0.48	0.060
Protection status	− 0.08	0.17	− 0.30	0.63	0.46	0.025
Conservation spending	− 0.18	0.23	− 0.11	0.14	0.69	0.015
GDP per capita	0.04	0.13	0.03	0.09	0.16	0.002
National governance	0.04	0.13	0.06	0.17	0.18	0.001

The table shows the averaged standardized and unstandardized regression coefficients along with their corresponding standard errors. The sum of weights of each variable and its partial pseudo-R^2 value are also provided

proportion of human pressure within their protected areas. Similarly, the relationship between human pressure and the protection status was also negative; the higher the percentage of protected land under strict status (i.e., IUCN categories I and II) the lower the proportion of intense human pressure. However, the amount of variance explained by these two variables was little and the size of their effect was small (Table 1). Conversely, most of the variation in the proportion of protected land under intense human pressure was explained by human population density, followed by the percent of agricultural land (Table 1). The countries' level of economic development and effectiveness of national governance related only weakly to their proportion of protected land under intense human pressure (Table 1).

Discussion

Several key messages can be extracted from the above analysis. First, there was no strong relationship between the proportion of protected land under intense human pressure and the effectiveness of national governance. This was true even when using the national governance metric of the Environmental Sustainability Index (Schmiedeknecht 2013), which is more relevant to environmental issues (Table S1). Considering that several studies have reported that successful conservation depends on effective national and local governance (Bruner et al. 2001; Smith et al. 2003; Wright et al. 2007; Lira-Noriega and Soberón 2015), one would expect that countries with stronger institutions are better able to curb intense human pressure within protected areas (Smith et al. 2003). I found no strong evidence for this pattern; in retrospect, this is understandable, considering that multiple countries that tend to score high on national governance (Waldron et al. 2013), including environmental governance (Schmiedeknecht 2013)—such as Netherlands, Austria, Belgium, and Israel—have also some of the highest proportions of protected land under intense human pressure (> 0.94). Conversely, other countries that tend to score low on national governance—such as Niger and Gabon—have very low proportions of protected land under intense human pressure. Moreover, it is also possible that the lack of a strong relationship between governance and human pressure was driven partly by the fact that local governance is likely to be more important for curbing human pressure within protected areas; however, the effectiveness of the local governance may not have been captured successfully by the national metrics.

There was also no significant relationship between the human pressure within protected areas and the economic development level of the countries (as measured using their per capita gross domestic product). This suggests that it may be possible—at least to a certain extent—to decouple economic development and human pressure within protected areas. In other words, it appears possible for countries to achieve their economic development goals and yet maintain much of their protected land under relatively low human pressure. Examples of such countries include Finland, Canada, Australia, and the United States. All four of them have less than 15% of their protected land under intense human pressure (Jones et al. 2018) and yet they have some of largest economies in the world. Conversely, countries such as Ghana, Bangladesh, and Tanzania have more than 80% of their protected land under intense human pressure, despite their lower economic development level. This finding, however, must be interpreted cautiously, because it is not possible to decipher from the analysis presented here whether the low levels of human pressure within the protected areas of those developed countries is actually a recent outcome, i.e., achieved following their economic development. It may be that economic development and human pressure within protected areas follow an inverted-*U* shaped relationship, similar to what would be expected by the Environmental Kuznets Curve theory (Mills and Waite 2009; Carson 2010).

In such case, developing countries would have to first tolerate elevated levels of human pressure within their protected areas before they develop the means and the conditions to reduce them (Carson 2010). That said, there appears to be no evidence for a Kuznets curve when one looks at the relationship between the proportion of protected land under intense human pressure and each country's GDP per capita (Figure S1). Similarly, other researchers have found no such pattern when examining, for instance, the relationship between national deforestation rates and economic development levels (Mills and Waite 2009).

The percentage of protected land under strict protection status was only weakly related to the levels of intense human pressure within protected areas (Table 1). As expected, countries with more of their protected land in IUCN Categories I and II had lower proportions of it under intense human pressure. However, this factor explained only a small amount of the variation in human pressure (Table 1). By now, several studies have demonstrated that the IUCN categories of the protected areas influence only minorly their effectiveness (Leroux et al. 2010; Jones et al. 2018; Leberger et al. 2019). These findings tend to be consistent regardless of the scale of the analysis or the metric used, e.g., rates of deforestation, changes in land-cover, or declines in animal population sizes (Leroux et al. 2010; Coetzee et al. 2014; Jones et al. 2018).

Conservation spending was also expectedly negatively related to the human pressure within protected areas; higher conservation spending was associated with less protected land under intense human pressure. The relationship, though, was also very weak; conservation spending accounted for only a small amount of the variation in human pressure within protected areas (Table 1). As interesting as this finding may be, it is important not to interpret it as if investments in conservation provide no substantial benefits in general. This finding is specific to human pressure within protected areas—as measured using the human footprint index—and, therefore, does not represent the overall relationship between spending and conservation. In fact, Waldron et al. (2017) have already shown that conservation spending has a positive effect on biodiversity, since on average it reduces loss by approximately 29% per country (Waldron et al. 2017). However, conservation spending—at least at the current levels—does not seem to be significantly associated with lower levels of human pressure within protected areas. That said, it is probable that larger investments are needed (Miller et al. 2013) to have a substantial effect on the levels of human pressure within the protected areas.

The three most important factors, which showed the strongest association with human pressure within protected areas, were human population densities, percent of agricultural land, and total land area of the country (Table 1). Countries with a higher population density, a larger percentage of agricultural land, and a smaller area had a higher proportion of their protected areas under intense human pressure (Fig. 1). This finding is important, because it suggests that under a business-as-usual scenario, countries with those characteristics are likely to struggle to keep their protected areas relatively free from intense human pressure—regardless of their economic development level, effectiveness of national governance, and current investments in conservation. In addition, this finding is important, because the population density of many countries—especially developing countries, many of which are located in biodiverse regions—is projected to increase during the next few decades (Cincotta et al. 2000; United Nations 2017). To complicate matters even further, the global demand for agricultural products will also increase—partly due to the growing human populations—resulting in further agricultural land expansion and intensification (Brussaard et al. 2010; Tscharntke et al. 2012; Ramankutty et al. 2018)—in many cases within some of the same countries (Molotoks et al. 2018). The combination of the above-mentioned two drivers (i.e., the increase of human population densities and demand for agricultural products) will likely make it even more difficult for the governments of those countries to conserve their biodiversity within protected areas.

A possible concern regarding the above conclusions is that the results of the analysis reflect the patterns in human pressure but not necessarily the patterns in biodiversity loss; human activities are not invariably incompatible with biodiversity conservation. Although this is true to a large extent, undoubtedly there is a strong negative relationship between the two (Newbold et al. 2016; Gray et al. 2016). For instance, studies have demonstrated that increases in human pressure—measured using the human footprint index—result in higher species extinction risks (Di Marco et al. 2018, 2019) and reduced animal movement (Tucker et al. 2018). Consequently, it is unlikely that countries will be able to conserve biodiversity successfully, and achieve their sustainability goals, without first addressing the levels of human pressure within their protected areas (Jones et al. 2018).

Two caveats, though, to consider when interpreting the results of this study. First, the analysis does not capture the variation in human pressure within the countries. Therefore, it does not necessarily reflect the factors that affect the effectiveness of protected areas at the local level (Levering-ton et al. 2010). Yet, since conservation policies are often designed and implemented at the national level, understanding the factors that influence human pressure at this level is undoubtedly essential. Second, the index used to measure human pressure (Jones et al. 2018), i.e., the human footprint index (Venter et al. 2016b), does not take into account several other types of human pressure, which also have a negative effect on biodiversity (Jones et al. 2018), e.g., pollution, overexploitation, and invasive species (Jones et al.

2018). Although these other types are likely to correlate with the pressures already included in the index (Jones et al. 2018; Bowler et al. 2020), it is not possible to know to what extent the factors identified here relate to those pressures. For example, it may be that national governance influences strongly the levels of pollution within protected areas.

Conclusion

Although studies often cite poor governance and lack of resources as two of the major reasons behind the ineffectiveness of protected areas, the findings presented here suggest that human population densities—and to a lesser degree the extent of agriculture—are probably more important in determining intense human pressure within protected areas. Countries—especially smaller area countries—aiming at reducing human pressure within their protected areas need to address high human population densities and to invest in efficient agricultural methods and policies, so that less land is required to meet the rising global demand for agricultural products (Ramankutty et al. 2018). Protected areas represent one of the most important conservation strategies for addressing the current rates of global biodiversity loss (Visconti et al. 2019) and for attaining the Sustainable Development Goals (Dudley et al. 2017); hence, it is imperative we understand and address the factors driving the levels of human pressure within the world's protected areas.

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