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Policy analysis

Evidence from eleven countries in four continents suggests that protected areas are not associated with higher poverty rates

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A B S T R A C T

Countries across the globe are expanding their networks of protected areas in an effort to address the increasing rates of biodiversity loss. Protected areas, though, have been criticized extensively for their negative impact on the local communities. Case studies have shown that protected areas can exacerbate poverty. However, these case studies represent only a small proportion of the over two-hundred thousand protected areas available worldwide today. Hence, it is possible that most protected areas do not impoverish the local communities. In fact, a few recent studies have suggested that protected areas do not impact negatively the local people. The findings of those studies, however, are based predominately on data from small geographical regions. Consequently, it is unclear whether their results are widely applicable. In this study, I have used a large dataset from 5800 administrative regions in eleven countries and four continents to explore in more detail the link between protected areas and local poverty rates. Particularly, I have used the quasi-experimental matching method to test whether administrative regions with protected areas have higher proportions of people living below the poverty line. I found no evidence to support this pattern. Protected areas do not appear to be associated with higher poverty rates. Considering that, firstly, biodiversity conservation and poverty alleviation represent two of the most urgent challenges of our time, and, secondly, that most efforts to conserve biodiversity are channeled through protected areas, it is crucial to know that protected areas do not interfere with our efforts to alleviate poverty.

1. Introduction

Protected areas represent one of the most important conservation strategies for addressing today's high rates of biodiversity loss (Miranda et al., 2016; Oldekop et al., 2016; Visconti et al., 2019). The percentage of protected land across the globe continues to rise (Geldmann et al., 2019) as countries intensify their efforts to achieve the globally agreed target of 17% (as described in the Aichi Target 11 of the Convention on Biological Diversity; Lewis et al., 2019). The importance of protected areas for biodiversity conservation has been such that researchers are calling for even more areas (Anderson and Mammides, 2019; Watson et al., 2016), with some scientists suggesting that to successfully conserve biodiversity we need to protect half of the planet (Locke, 2014; Pimm et al., 2018; Wilson, 2016). However, protected areas have been criticized, occasionally fiercely, for impacting the livelihoods of the local people, particularly those in the developing world (Cernea and Schmidt-Soltau, 2006; Vedeld et al., 2012; West and Brockington, 2006). This criticism has evolved into a contested, yet unresolved debate (Brockington et al., 2012; Brockington and Wilkie, 2015; Wilkie et al., 2006), which is often associated with the broader dissension regarding the link between biodiversity conservation and poverty alleviation—two of the most important challenges of our time (Adams et al., 2004; Gardner et al., 2013; Turner et al., 2012).

On one end, there is the argument that biodiversity conservation and poverty alleviation are unrelated targets and must be kept as such (Adams et al., 2004; Terborgh, 2004). The proponents of this stance warn that if the two are linked, we risk compromising the success of both (Terborgh, 2004) because of the intrinsic tradeoffs (Ferraro and Hanauer, 2011). Under this viewpoint, the argument specific to protected areas is that their purpose is to safeguard biodiversity; therefore, they should not be required to also address the needs of the local people (Terborgh, 2004). Such viewpoints encourage restrictive conservation approaches—oftentimes referred to as "fortress conservation" (Igoe, 2004). Restrictive approaches deem local people's activities as incompatible with conservation (Terborgh, 2004) and thus efforts are made to exclude them from protected areas.

Conversely, there is the argument that biodiversity conservation and poverty alleviation are naturally interrelated targets (Adams and Hutton, 2007; Fisher et al., 2012; Turner et al., 2012). Proponents of this viewpoint argue that appropriately designed conservation

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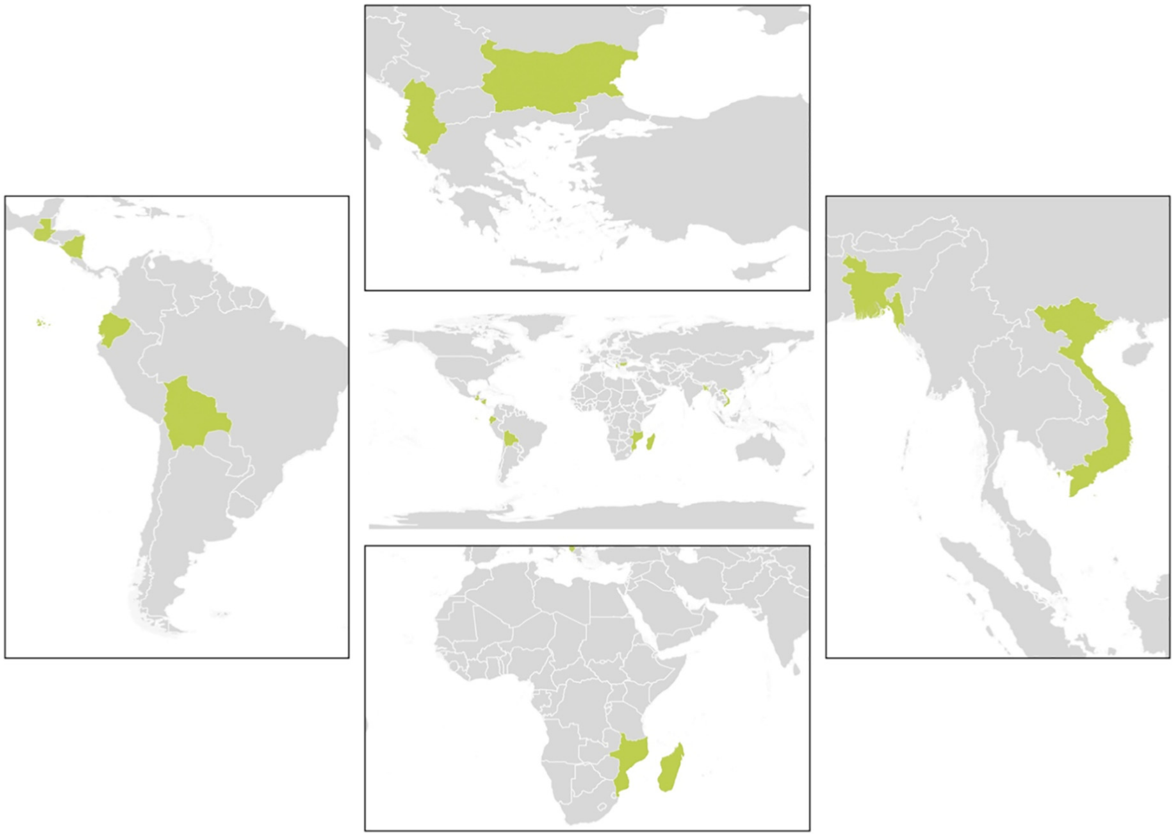

Fig. 1. Map of the eleven countries used in the analysis: Albania, Bulgaria, Bangladesh, Vietnam, Malawi, Mozambique, Madagascar, Ecuador, Bolivia, Guatemala, Nicaragua.

measures, including protected areas, could benefit local people (Turner et al., 2012). Importantly, they also argue that conservation measures cannot succeed, especially in the long-term, if they are not supported by the local communities (Andrade and Rhodes, 2012; Brockington and Wilkie, 2015; Wells and McShane, 2004). Protected areas in this case have the dual role of safeguarding biodiversity while also contributing to the livelihoods of the local people (Wells and McShane, 2004).

In between lies a third argument, which suggests that protected areas need to foremost protect biodiversity and natural environments, but they must do so without affecting disproportionately the local people (Roe and Elliott, 2004). This may be the mostly widely accepted stance—ingrained also in the Aichi Target 11 of the Convention on Biological Diversity, which states that when it comes to protected areas, local communities "should not bear inequitable costs"(Clements et al., 2018). Unfortunately, however, there has been a plethora of examples in the literature (e.g., Cernea and Schmidt-Soltau, 2006; West et al., 2006; West and Brockington, 2006), which show that local communities have, in fact, suffered disproportionate and substantial costs due to protected areas (Adams and Hutton, 2007; Brockington and Wilkie, 2015). These examples appear not to be isolated cases but rather repeated incidents that have occurred across multiple parts of the planet (Cernea and Schmidt-Soltau, 2006; West and Brockington, 2006). Perhaps more importantly, most of these incidents have occurred in developing countries, where local people are the most vulnerable (Cernea and Schmidt-Soltau, 2006; Kepe et al., 2004; Morris and Vathana, 2003).

Protected areas can affect local people in developing countries through multiple pathways (West and Brockington, 2006). For instance, restrictions often associated with the management of protected areas may limit local people's access to key natural resources, such as agricultural land, grazing grounds, timber and other forest products (West et al., 2006; West and Brockington, 2006). These resources may be essential to the economic survival of those local people (West and Brockington, 2006). Even in the cases where the impact is not as immediate and austere, protected areas may still affect the local communities, e.g., by inhibiting the economic development of a region, through the prohibition or discouragement of related projects, which may conflict with the conservation targets of those areas.

Although those cases of protected areas that have led to the impoverishment of the local communities are undoubtedly troublesome (West and Brockington, 2006), the reality is that currently we do not know how representative they are of protected areas in general (and of their impact on local livelihoods). There are more than two-hundred thousand protected areas across the globe (Qin et al., 2019) and consequently collectively the aforementioned cases represent only a small proportion of the total number of protected areas. It is possible that their negative impact on the local people in developing countries is not the norm but rather the exception. The prominence of those cases in the academic literature could be the result of a disproportionate focus on protected areas that have had severe impacts on the local communities. Understandably, such cases are more likely to draw the attention of researchers due to the magnitude of the impact. Hence, it is possible that the effects of protected areas in general are not detrimental. This possibility remains unclear and needs to be researched further.

In fact, a growing body of literature now suggests that local communities living within and in proximity to protected areas are not affected by them negatively (Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014; Dudley et al., 2010a; Naidoo et al., 2019; Naughton-Treves et al., 2011). In some cases, local communities may even benefit from protected areas (Andam et al., 2010; den Braber et al., 2018; Dudley et al., 2010a; Naidoo et al., 2019)—through several mechanisms (Ferraro and Hanauer, 2014), such as increased ecosystem services and tourism (den Braber et al., 2018; Naidoo et al., 2019). However, the few studies available that

Table 1
List of countries used in the analysis as well as information regarding their average poverty rates (FGT headcount index), number of administrative units, average area per unit (km^2), number of protected areas, number of units classified as protected (i.e., with ≥10% of their area covered by protected areas), and average area within protected units covered by protected areas. The percentage of protected areas belonging to the various IUCN categories is also shown. The column "Year" represents the year when the data on poverty rates were collected within each country.

Country	Administrative division level	Year	Average FGT headcount index	Number of units	Average unit area (km^2)	Number of protected areas	Number of protected units	Average protected area within units (%)	Strict reserves (I–II) %	Non-strict reserves (III–VI) %	No category reported %
Albania	Second	2001	0.35	374	76	51	28	27	25	57	18
Bulgaria	Second	2001	0.15	262	426	684	28	26	8	89	2
Ecuador	Second	2001	0.58	181	773	28	18	31	7	4	89
Guatemala	Second	2002	0.64	330	330	152	62	48	10	52	38
Madagascar	Second	1993	0.71	111	5357	41	9	16	44	56	0
Malawi	Second	1998	0.63	31	3106	61	15	28	8	8	84
Mozambique	Second	1997	0.69	146	5414	66	27	42	14	14	73
Nicaragua	Second	1995	0.29	143	837	77	49	36	5	62	32
Vietnam	Second	1999	0.42	614	537	56	33	27	18	63	20
Bangladesh	Third	2001	0.43	481	282	20	15	37	40	50	10
Bolivia	Third	2001	0.77	314	3461	127	72	38	4	9	87
Ecuador	Third	2001	0.66	813	172	28	58	39	7	4	89
Madagascar	Third	1993	0.73	1238	479	41	55	32	44	56	0
Malawi	Third	1998	0.59	351	269	61	46	53	8	8	84
Mozambique	Third	1997	0.69	411	1921	66	57	52	14	14	73

suggest that protected areas do not exacerbate poverty are for the most part also based on data from limited geographical regions, i.e., from one or two countries at most (e.g., Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014; Ferraro et al., 2011; Hanauer and Canavire-Bacarreza, 2015; Miranda et al., 2016; Naughton-Treves et al., 2011). The only exception is perhaps a recent study by Naidoo et al. (2019), which explored the impact of protected areas on people's well-being and health in > 60,000 households across the developing world. However, more studies are needed to understand the impact protected areas may have on the local communities (Brockington and Wilkie, 2015; Naidoo et al., 2019). Such studies should ideally use standardized information from multiple countries and broad geographical regions (Brockington and Wilkie, 2015; Ferraro and Hanauer, 2015; Hanauer and Canavire-Bacarreza, 2015).

Here, I use a large dataset on poverty and inequality (CIESIN, 2005)—available for 5800 administrative regions in eleven developing countries in four continents (Africa, Asia, Europe, and Latin America; Fig. 1)—to explore the relationship between protected areas and local poverty rates (Ferraro et al., 2011). Specifically, I assess whether poverty rates are higher in regions with protected areas vs. regions with no protected areas (Canavire-Bacarreza and Hanauer, 2013). The rationale behind this particular analysis is that if protected areas lead consistently to the impoverishment of the local communities then we would expect protected regions to show on average higher rates of poverty. First, I compare the poverty rates within regions with protected areas to all regions without protected areas (what is often termed in the literature as the "naïve comparison"; Andam et al., 2010). Then, I use the quasi-experimental matching technique (Andam et al., 2010; Ho et al., 2011; Mccaffrey et al., 2013) to compare regions with protected areas to regions without such areas, but with similar characteristics in terms of other key factors that influence local people's poverty rates, e.g., access to economic centers and extent of infrastructure (Canavire-Bacarreza and Hanauer, 2013; Joppa and Pfaff, 2011). This comparison is essential because it is possible that protected regions have higher poverty rates due to factors other than presence of protected areas (Andam et al., 2010). This high-resolution, standardized, multi-national dataset allows us to test widely the recent hypothesis put forward that protected areas are not associated with increased poverty rates (Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014; Naidoo et al., 2019).

2. Materials and methods

2.1. Data on poverty and protected areas

I first downloaded the data on poverty and inequality, published online by the Socioeconomic Data and Applications Center (SEDAC) at http://sedac.ciesin.columbia.edu (CIESIN, 2005). The data were collected within the framework of the "Poverty Mapping Project" led by the Center for International Earth Science Information Network (CIESIN) at Columbia University in the US. The purpose of the project was to collect globally consistent, high-resolution estimates of poverty across the world (CIESIN, 2005). The data cover countries in Africa, Asia, Europe, and Latin America, and were collected between the years of 1992 and 2005 (CIESIN, 2005). For each country, the data include a series of measures of poverty. For the purposes of the analysis here, I used the "Foster-Greer-Thorbecke (FGT) poverty measure" (Foster et al., 2010), and particularly the "headcount index", which was available for all countries. The specific index represents the proportion of the population living below the poverty line within each country's administrative units at the second and third division levels (CIESIN, 2005). Countries across the globe are organized into multiple administrative division levels; the zero level represents the entire country while each subsequent level represents a further subnational division (e.g., states, provinces, etc.). Although the exact delineations vary from country to country, the second level usually refers to districts (or analogous units) while the third level refers to municipalities and communities. I only included in the analysis those countries for which the index was available spatially (n = 11; Fig. 1). Having the spatial distribution of the poverty index was essential in order to link poverty rates to protected areas (Fig. S1) and the rest of the covariates used in the analysis (see below for a full description of each covariate). For nine of the eleven countries, the poverty index was available at the second administrative level—resulting in 2192 administrative units (Table 1)—and for six of the countries the index was available at the third level—resulting in 3608 units (CIESIN, 2005). For four countries the index was available at both levels (CIESIN, 2005). To assess the effect of scale on the results—and therefore the extent to which the findings are robust—I ran the analysis, which is described in detail below, separately for each administrative level.

To obtain the spatial boundaries of the protected areas within each country, I used the World Database on Protected Areas (WDPA; October 2018 version) available online at https://protectedplanet.net.

Following the guidelines for best practices, prepared by UNEP-WCMC and available at https://www.protectedplanet.net/c/calculating-protected-area-coverage, I removed from the analysis protected areas not yet established, i.e., areas with "proposed" status. In addition, I removed areas that were established after the poverty index was compiled within each country (Table 1); this was necessary in order to eliminate temporal mismatches among the data used. A few of the protected areas in the database lacked an establishment year. Following the methods of previous studies (e.g., Jones et al., 2018), I randomly assigned to those areas an establishment year based on the years of the rest protected areas in the country (Anderson and Mammides, 2019; Jones et al., 2018). In general, protected areas are classified into different categories based on their objectives and management strategies (Leroux et al., 2010). The International Union for Conservation of Nature (IUCN) recognizes six categories of protected areas (Leroux et al., 2010), ranging from strict nature reserves (category Ia) to areas where natural resources can be used sustainably (category VI). Since the management strategies of the six categories vary (Dudley et al., 2010b), it is possible that they affect the local communities dissimilarly. To explore this possibility, and following previous studies (Anderson and Mammides, 2019; Jones et al., 2018), I grouped protected areas within each country into: (a) strict reserves (categories Ia, Ib, and II); (b) non-strict reserves (categories III–VI); and (c) reserves with no category reported. This information, though, was only used qualitatively and was not incorporated into the matching analysis because the resulting data were highly unbalanced and the sample sizes were relatively low (Table 1). For instance, no IUCN category was reported for numerous protected areas, within several countries (Table 1). In other countries, protected areas belonged mostly to one group but not the rest (Table S1). Therefore, I treated all protected areas equally—as was done in other related studies (e.g., Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013)—and used ArcMap (version 10.2) to dissolve the polygons to avoid double counting areas with overlapping ranges (Jones et al., 2018).

2.2. Quasi-experimental matching analysis

Previous studies have demonstrated that protected areas tend to be situated in remote regions (Joppa and Pfaff, 2009) where the land is often less suitable for human uses, e.g., agriculture (Joppa and Pfaff, 2009; Visconti et al., 2019). Consequently, to be able to evaluate correctly any differences between protected areas and non-protected areas it is important to control for biases due to non-random confounding factors (Andam et al., 2010; Anderson and Mammides, 2019; Joppa and Pfaff, 2009). It is possible that people living within and near protected areas are poorer not because the areas are being protected but because such areas tend to be situated in isolated rural regions (Canavire-Bacarreza and Hanauer, 2013; Joppa and Pfaff, 2009). Isolated rural regions often offer fewer economic opportunities and therefore it becomes more difficult for local people to escape poverty. Biases due to confounding factors can be reduced using the quasi-experimental method called "matching" (Ho et al., 2011; Joppa and Pfaff, 2010; Ramsey et al., 2019), through which regions with protected areas are matched and compared to regions with no protected areas but with similar characteristics in terms of other important variables (Ramsey et al., 2019).

For the purposes of this analysis, I used the matching method to control for the following factors, shown in the literature to be related to poverty rates and protected areas (Anderson and Mammides, 2019; Canavire-Bacarreza and Hanauer, 2013; Joppa and Pfaff, 2009):

1. Elevation and slope. Protected areas tend to be placed in areas with higher elevations and steeper slopes (Canavire-Bacarreza and Hanauer, 2013; Joppa and Pfaff, 2011, 2009; Nelson and Chomitz, 2011). Such areas are usually less suitable for agriculture and/or other human uses (Joppa and Pfaff, 2009) and therefore are more likely to be associated with higher poverty rates, regardless of their protection status (Canavire-Bacarreza and Hanauer, 2013). Using ArcMap and the topographical data made available by Amatulli et al. (2018), I calculated each administrative unit's mean elevation and slope (in meters and degrees respectively);
2. Distance to the nearest major city. Rural communities closer to large cities (which usually represent the economic centers of a country) are more likely to have increased access to economic opportunities (Canavire-Bacarreza and Hanauer, 2013; Joppa and Pfaff, 2011; Nelson and Chomitz, 2011) and hence less likely to have increased poverty rates (Canavire-Bacarreza and Hanauer, 2013). Protected areas, however, are usually located far from such economic centers (Joppa and Pfaff, 2009). To control for this bias I calculated the distance, in km, between each administrative unit and the nearest major city within each country (Canavire-Bacarreza and Hanauer, 2013), using the World Cities dataset made available by ESRI at https://hub.arcgis.com/datasets;
3. Human footprint index. The index is a composite measure of human presence (Venter et al., 2016), which includes a series of key factors that are all associated with the economic potential and the output of a region (Joppa and Pfaff, 2011, 2009). Particularly, it includes factors such as the extent of built-up areas, agriculture (i.e., croplands and pastures) and infrastructure (i.e., roads and railways). Also, it includes a measure of human population densities (Venter et al., 2016), which represents another key factor to consider when comparing poverty rates between regions. To control for such differences I calculated each administrative unit's mean human footprint in 1993, i.e., the earliest of the two years for which the index is available (Venter et al., 2016) and the year prior to when the poverty indices were collected.

2.3. Data analysis

To understand better the variation in poverty rates across the eleven countries—and to confirm that the factors used in the matching analysis capture successfully the poverty rates—I used the random forest technique (Cutler et al., 2007), a supervised machine learning method, to run a regression model for each administrative level, with the proportion of people living below the poverty line as the response variable and the following six variables as predictors: (1) mean elevation; (2) mean slope; (3) distance to the nearest major city; (4) mean human footprint; (5) percentage of protected land within each unit; and (6) country. An advantage of the random forest technique over conventional regression methods (e.g., the multiple linear regression) is that it does not assume linearity and handles unbalanced data better (Cutler et al., 2007). To confirm that collinearity between the predictors was not an issue, I calculated the corresponding bivariate Pearson's correlation coefficients (Table S2). Both random forest models showed that the identity of the country was a strong predictor of the poverty rates within each administrative unit. Therefore, to avoid inaccuracies that could result from comparing units situated in different countries, I ran all subsequent analyses separately for each country.

To build the matched dataset for each country, I first classified administrative units into "protected" and "non-protected" based on the extent of protected areas within their boundaries (Canavire-Bacarreza and Hanauer, 2013). Following previous studies (e.g., Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013), I classified units as "protected" if at least 10% of their territory was covered by protected areas (Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013), and as "non-protected" if there were no protected areas at all. I excluded all units in-between (i.e., with > 0% of protected land but < 10%) to avoid weakening the effect of protected areas, if present (Canavire-Bacarreza and Hanauer, 2013). Using the "matchit" package in R (Ho et al., 2011) and the "nearest neighbor" approach ("mahalanobis" distance), I matched each protected unit to a non-protected unit while controlling for differences in: (1) mean elevation; (2) mean slope; (3)

distance to the nearest major city; and (4) mean human footprint. Using the "cobalt" package in R (Greifer, 2019), I evaluated the balance in the resulting matched dataset by measuring the mean standardized difference between protected and non-protected units (Ramsey et al., 2019) for each of the four controlling variables (Mccaffrey et al., 2013). Using the final dataset, I ran a Wilcoxon ranked test for each country to assess whether the proportion of people living below the poverty line was on average higher within protected administrative units compared to non-protected.

2.4. Sensitivity tests

To ensure that results were robust and not sensitive to specificities associated with the methods and the data used, I ran two supplementary analyses:

1. In addition to the "mahalanobis" distance, I also matched administrative units using the "logit" distance (Ho et al., 2011) and using calipers (which I set to 0.5 standard deviations; Andam et al., 2008). Calipers are essentially used to restrict the maximum differences between the matched units (Andam et al., 2008). Additionally, I used the "sensitivityR5" package in R to perform a Rosenbaum bounds sensitivity analysis (Rosenbaum, 2002). The purpose of the analysis is to calculate how much unobserved bias would be needed to nullify the results (Canavire-Bacarreza and Hanauer, 2013). Unobserved bias is essentially bias that was potentially unaccounted during the matching analysis. If large amounts of unobserved bias are needed to nullify the results then the findings can be considered robust (Canavire-Bacarreza and Hanauer, 2013; Rosenbaum, 2002).
2. For the third administrative level—for which there were more units per country, and therefore larger sample sizes—I repeated the analysis using a higher threshold of protected land (i.e., ≥30% instead of ≥10%). The rationale behind this analysis was that the negative effects of the protected areas could be detectable only after a significant portion of each administrative unit became covered by protected areas.

3. Results

Overall, the proportion of people living below the poverty line, as measured using the FGT index (Foster et al., 2010) ranged from 0 (in some units in Albania, where there were no people below the poverty line) to 1 (in units in Bolivia, where the whole population was below the poverty line). At the second administrative level, Bulgaria had on average the lowest poverty rates (mean = 0.15) while Madagascar the highest (mean = 0.71; Table 1). At the third level, the lowest average poverty rates were in Bangladesh (mean = 0.43) and the highest in Bolivia (mean = 0.77). The number of administrative units classified as protected varied depending on each country's total number of units and total number of protected areas (Table 1). On average, countries at the second administrative level had 18% of their units classified as protected and countries at the third level 11%. Of the units that were classified as protected, many were covered completely by protected areas (especially at the third administrative level; Fig. S1). On average, protected areas covered 31% of the area of the protected units at the second administrative level and 42% of their area at the third level (Table 1). There was variation in terms of the categories to which the protected areas of each country belonged (Table S1). In some countries, such as Bulgaria, protected areas belonged mostly to "non-strict reserves" (Table 1), while in others, such as Ecuador, Bolivia, and Malawi, no IUCN category was not reported for most of the protected areas (> 80%).

The random forest model at the second administrative level explained 77% of the variation in poverty rates; country was the most important predictor (Table 2; Fig. S2). The least important predictor was the percentage of protected land within each unit (Table 2). The random forest model at the third level explained 56% of the variation in poverty rates. The most important predictor at this level was the mean human footprint, while the least important was again the percentage of the unit covered by protected areas (Table 2).

Table 2
Results of the random forest regression models at the second and third administrative levels showing the importance of each of the six predictors, as well as the variation in poverty rates explained by each model. Variable importance represents the percentage by which the mean square error (% Inc. MSE) increases when each variable is omitted from the model. The higher the value the higher the importance.

Variable	Level 2 R^2 = 0.77 % Inc. MSE	Level 3 R^2 = 0.56 % Inc. MSE
Elevation (m)	58.1	78.6
Slope (°)	70.3	61.5
Human footprint value	86.6	107.2
Nearest city (km)	69.8	95.9
Protected areas (%)	20.3	15.6
Country	228.9	94.0

3.1. Naïve comparisons

When protected and non-protected units were compared before they were matched (i.e., using all available units), the poverty rates in five of the nine countries at the second administrative level were on average higher within the protected units (Table 3; Fig. S3). The difference, though, was statistically significant only for Mozambique (Table 3). In the other four countries, the rates were on average higher within the non-protected units, but only statistically significant for Bulgaria (Table 3). At the third administrative level, poverty rates were higher within protected units in four out of the six countries (Fig. S4) and statistically significant for two of those: Malawi and Mozambique (Table 3). In the remaining two countries, Bolivia and Madagascar, the poverty rates were lower within protected units and were statistically significant (Table 3).

3.2. Matched comparisons

When the same comparisons were made using the matched data, the differences in poverty rates between protected and non-protected units were not statistically significant for any of the countries examined at any of the administrative levels (Figs. 2 and 3). The same results were found when units were matched using the "logit" distance and calipers (Table S3). The only exception was Guatemala in which poverty rates were lower within protected units, as previously, but the result was now statistically significant (p-value = 0.04; Table S3). In terms of the sensitivity of the results to possible unobserved variation, the Rosenbaum bounds analysis confirmed that the results were robust (gamma values ≥1; Tables S4 and S5). The only exception was Madagascar, but only at the third administrative level and not the second (Table S5). Note that similarly to Guatemala, the poverty rates in Madagascar were on average lower inside protected units (Table S3). Therefore, even if we were to assume that there was some unobserved bias, which could potentially nullify the results, then the conclusion would be that protected areas in Madagascar (at the third administrative level) are associated with lower poverty rates—not higher (Figs. 2 and 3).

When a higher threshold of protected land was used, i.e., ≥30%, results matched those found earlier (Table S6), showing no statistically significant difference between protected and non-protected units. Compared to the naïve comparisons, the matching method had reduced substantially the mean differences between the protected and non-protected units for all four controlling variables (Figs. S5 and S6). The balance was satisfactory, albeit superior at the third administrative

Table 3
Results of the Wilcoxon ranked tests using the matched units at the second and third administrative levels showing the differences in poverty rates between protected and non-protected units. Positive z-values mean that poverty rates are on average lower inside protected units while negative values mean the opposite. The table includes the results of the naïve comparison, i.e., when all units were used, as well as the number of matched units and the corresponding percentage.

Country	Level	Matched units	% of units matched	Matched comparison		Naïve comparison	
				z	p-Value	z	p-Value
Albania	Second	54	16.8	1.33	0.19	0.17	0.87
Bulgaria	Second	43	43.4	1.96	0.05	2.10	0.04
Ecuador	Second	29	18.6	0.17	0.86	−0.68	0.50
Guatemala	Second	98	39.5	0.54	0.59	1.17	0.24
Madagascar	Second	15	23.1	0.47	0.64	1.35	0.18
Malawi	Second	17	89.5	−1.64	0.10	−1.40	0.16
Mozambique	Second	43	36.1	−1.58	0.11	−3.33	0.001
Nicaragua	Second	72	67.9	0.37	0.71	−1.13	0.26
Vietnam	Second	62	11.5	0.72	0.47	−1.95	0.05
Bangladesh	Third	28	6.0	−0.58	0.56	−0.70	0.48
Bolivia	Third	116	48.5	1.66	0.10	3.69	< 0.001
Ecuador	Third	95	12.4	1.02	0.31	−1.11	0.27
Madagascar	Third	103	9.0	1.85	0.06	3.07	0.002
Malawi	Third	82	31.9	−0.38	0.70	−2.04	0.04
Mozambique	Third	103	27.8	−1.10	0.27	−4.05	< 0.001

level, mainly because of the higher resolution and the higher sample size (Figs. S5 and S6).

4. Discussion

The findings of the study here suggest that protected areas in developing countries are not associated with higher poverty rates as measured using the FGT headcount index (Foster et al., 2010). When administrative units were analyzed using the random forest technique, the identity of the country was consistently one of the strongest predictors of the FGT headcount index (Table 2; Fig. S2). This indicates, unsurprisingly, that the percentage of people living below the poverty line within each unit is largely determined by the socioeconomic status of the country in which the unit is located. In contrast, protected areas—specifically the percentage of administrative units covered by protected areas—was the least important variable, explaining little of the variation in poverty rates (Table 2). When protected units were compared to all unprotected units within each country (i.e., during the naïve comparisons), results were statistically significant for five out of the eleven countries. In two of those countries, Malawi and Mozambique, the poverty rates were higher within protected regions. However, once comparisons were made following matching, the poverty rates between protected and non-protected units did not differ much, nor were they statistically significant for any of the countries (Table 3).

Hence, the results of the matching analysis provide strong evidence that protected areas in developing countries do not exacerbate poverty rates (Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014). Moreover, the scale at which the analysis was conducted—spanning eleven countries in four continents—suggests that the findings can be perhaps generalized broadly. Importantly, the analysis overcomes some of the limitations in previous studies. For instance, Andam et al. (2010)—who also found that protected areas do not exacerbate poverty rates—mentioned that it was not clear how generalizable their results were because their analysis was based on data from Costa Rica and Thailand. According to them, both countries had experienced considerable economic growth and therefore they may not have been representative of developing countries in general. Conversely, the analysis presented here is based on data from developing countries that cover a wider socioeconomic spectrum—a fact that is also reflected in their average FGT headcount indices (Table 1). Subsequently, it can be argued that the findings here are applicable to many developing countries; even some of the least developed countries, like Madagascar and Mozambique, where local people may depend more on nearby

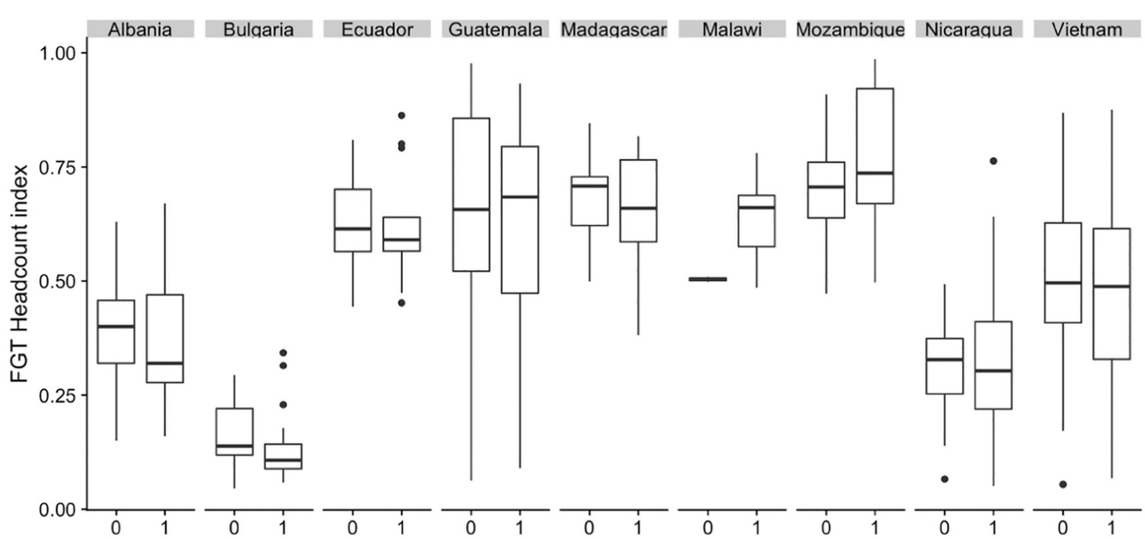

Fig. 2. The poverty rates at the second administrative level varied extensively between the countries, but the differences between protected administrative units (1) and matched non-protected units (0) within each country were not substantial or statistically significant.

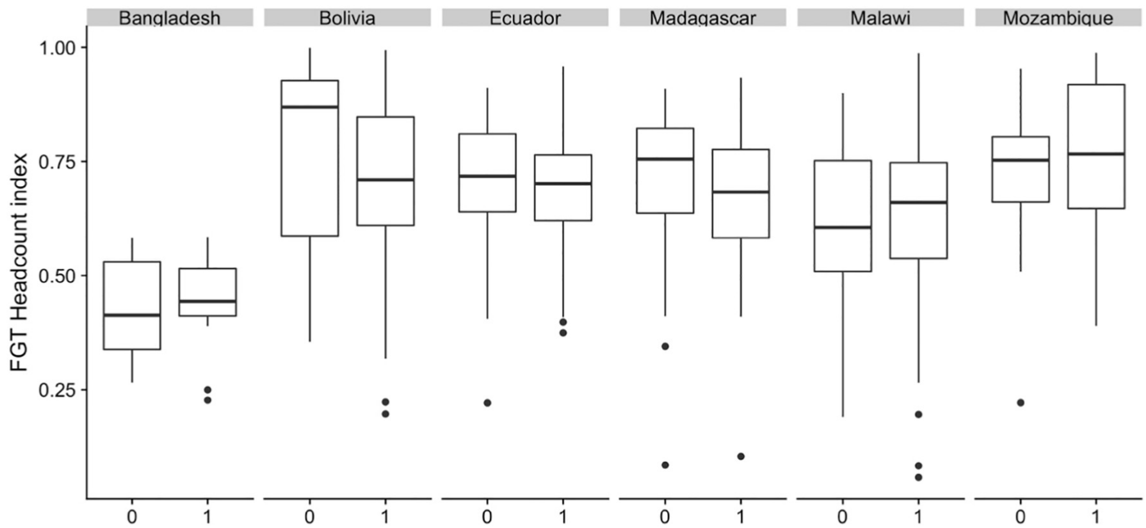

Fig. 3. The differences in poverty rates between protected administrative units (1) and matched non-protected units (0) were not substantial or statistically significant for any of the countries examined at the third administrative level.

natural resources and may have fewer alternative economic opportunities. Moreover, the findings are not restricted to specific geographical regions. The geographical variation captured by the eleven countries is important because previous studies had focused mostly on countries in Latin America and Asia (Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014).

It is possible that the IUCN categories of the protected areas do not have a strong influence on the reported results. Although, it was not feasible to confirm this explicitly through the matching analysis, the fact that countries like Madagascar and Bangladesh show the same patterns as the other countries—despite having > 40% of protected areas belonging to strict categories (Table S1)—suggests that the findings may be applicable to all categories. In fact, in Madagascar the poverty rates were on average lower within protected regions, although this pattern was not statistically significant. Additionally, it should be noted that many of the protected areas for which the IUCN category was not reported (e.g., more than > 89% of the protected areas in Ecuador) are also likely to be under some kind of a strict management status (Naughton-Treves et al., 2006). Nonetheless, the potential influence of the IUCN categories on the poverty rates remains to be explored in future studies using more detailed data.

The fact that the results of this study concur with those of other studies, which addressed similar questions but used different poverty indices, suggests that the findings are robust and not specific to the FGT poverty index (Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014; den Braber et al., 2018; Ferraro et al., 2011). For example, Clements et al. (2014) found also no link between protected areas and poverty rates (using data from two protected areas in Cambodia) but their analysis was based on three indices other than the FGT index. Canavire-Bacarreza and Hanauer (2013) found similar results in Bolivia using indices of poverty rates that were measuring the assets owned by the local people and their unsatisfied basic needs. Bolivia was included also in this analysis and the results (using the FGT index) were in agreement. Naidoo et al. (2019), which is one of the few studies, apart from the present study, that used data from several countries, found also that protected areas do not affect negatively the local people, specifically their health and well-being.

In fact, Naidoo et al. (2019) found that in some cases local people may even benefit from protected areas. Naidoo et al. (2019) explored the possible mechanisms behind those benefits and found that improved ecosystem services and increased tourism were the most probable reasons. The positive effect of tourism was also mentioned by Ferraro and Hanauer (2014) and den Braber et al. (2018), who looked at the relationship between poverty rates and protected areas in Costa Rica and Nepal respectively. However, in my analysis of the eleven countries I found no examples in which protected units had on average statistically significant lower poverty rates compared to their matched non-protected units (Table 3). The only exception was Guatemala but only when the alternative matching algorithm was used (p-value = 0.04; Table S3); Bulgaria and Madagascar (at the third administrative level) showed similar trends with the corresponding p-values being 0.05 and 0.06 respectively (Table 3). Perhaps these results indicate that the positive effects of protected areas, reported in some of the aforementioned studies (den Braber et al., 2018; Naidoo et al., 2019), may be applicable to other countries as well but not as widespread.

A potential caveat of this study—and studies such as this one, which are based on spatially aggregated data (Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013)—is that the analysis does not distinguish between people living within the protected areas vs. people living nearby. It is possible that people within protected areas are impacted disproportionately but the effect is diluted when poverty rates are aggregated at the administrative unit level. This is unlikely to be a major issue, though, because the results of the supplementary analysis presented here, which uses a higher threshold of protected land—i.e., ≥30% vs. ≥10% that is usually used in the literature (Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013)—produces the same findings (Table S3). Also, note that in some of the countries, e.g., in Malawi and Mozambique, the average percentage of protected land was already high, exceeding 50% (Table 1). Moreover, the aforementioned possibility does not affect in any way the overall conclusion of the study, i.e., that the proportion of people living below the poverty line within protected administrative units is not higher than the corresponding proportion in similar non-protected units.

It is important, however, not to interpret the above finding as if protected areas have no effects on any of the local people. Although on average local communities within protected administrative units do not exhibit higher poverty rates, certain households, within those units, may have suffered substantial consequences if their economic opportunities have been lessened by restrictions associated with the establishment of the protected areas (Poudyal et al., 2018). Moreover, protected areas may have had other, non-monetary effects on the local people, which could not have been captured in this analysis (Oldekop et al., 2016). It is positive, though, that on average protected areas do not exacerbate local poverty rates in developing countries (Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014; den Braber et al., 2018). This is important because national and international organizations around the globe are spending immense resources and efforts to reduce poverty and to conserve biodiversity (Naidoo et al., 2019). Poverty alleviation and biodiversity conservation represented key targets of the United Nations Millennium Development Goals (Canavire-Bacarreza and Hanauer, 2013) and are also included in the more recently updated Sustainable Development Goals (Lewis et al., 2019). Since most efforts to conserve biodiversity are channeled through protected areas (Lewis et al., 2019; Qin et al., 2019), it is crucial to know whether progress made towards one goal jeopardizes the efforts towards the other (Andam et al., 2010). The results presented here, and the results of the other studies (e.g., Clements et al., 2014; Naidoo et al., 2019), suggest that this is not the case. Moreover, they suggest that protected areas may even benefit local people (Naidoo et al., 2019), resulting potentially into win-win scenarios (den Braber et al., 2018; Naidoo et al., 2019). This prospect paints a different picture from the one presented oftentimes in the literature, which suggests that protected areas are poverty traps. Perhaps those protected areas that have been shown to have had significant impact on the local people (West et al., 2006; West and Brockington, 2006) are not representative of protected areas in general.

However, the biodiversity conservation–poverty alleviation nexus requires further research (Adams et al., 2004; Fisher and Christopher, 2007). First, more analyses, such as this one, are necessary to evaluate further the extent to which the results are applicable. The number of protected areas analyzed here and in similar studies still represents a relatively small percentage of the total number. Second, as more data on local livelihoods become available, it is important that future studies measure poverty and local livelihoods using other, multidimensional indices (Bourguignon and Chakravarty, 2003; Naidoo et al., 2019). Although the index used here is different from what other studies have used (Canavire-Bacarreza and Hanauer, 2013; Clements et al., 2014), it is still capturing similar aspects of poverty, overlooking other important dimensions (Bourguignon and Chakravarty, 2003). Lastly, the analysis here, and the analyses in similar studies (e.g., Andam et al., 2010; Canavire-Bacarreza and Hanauer, 2013), do not explore in depth the potential differences between the various categories of protected areas (Dudley et al., 2010b). This is mostly because of restrictions associated with the available data. It remains possible, however, that some categories of protected areas have a larger impact on local people than others (Naidoo et al., 2019; Oldekop et al., 2016) and this must be explored in more detail in future studies.

5. Conclusion

Protected areas represent the most important conservation strategy for addressing today's high rates of biodiversity loss (Watson et al., 2014). As a result, the percentage of protected land across the globe continues to increase (Geldmann et al., 2019; Jones et al., 2018). Many stakeholders have been concerned about the possible impact of protected areas on the local communities (West and Brockington, 2006), particularly in the developing world. Past studies have shown that protected areas can affect negatively the local people (Oldekop et al., 2016; West and Brockington, 2006) and can act as poverty traps. The extent, though, to which this is true for many of the world's protected areas remained unclear. The results of this study—which is one of the few to explore the link between protected areas and poverty at this scale—suggest that protected areas are not associated with higher poverty rates in developing countries. Conservation efforts, which focus largely on protected areas, appear not to interfere with the efforts to alleviate poverty. Considering the importance of addressing biodiversity loss and eliminating poverty (Adams et al., 2004,) and the fact that much of the world's biodiversity is found in regions with high poverty rates (Fisher and Christopher, 2007), it is encouraging that protected areas do not to exacerbate poverty.

CRediT authorship contribution statement

Christos Mammides: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The author declares no conflict of interest associated with this study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2019.108353.

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