WPS7091

Policy Research Working Paper 7091

Protected Areas and Deforestation

New Results from High Resolution Panel Data

Brian Blankespoor
Susmita Dasgupta
David Wheeler

WORLD BANK GROUP
Development Research Group
Computational Tools Team and Environment and Energy Team
November 2014

Policy Research Working Paper 7091

Abstract

This paper investigates the effectiveness of protected areas in slowing tropical forest clearing in 64 countries in Asia/Pacific, Africa, and Latin America for the period 2001–2012. The investigation compares deforestation rates inside and within 10 kilometers outside the boundary of protected areas. Annual time series of these deforestation rates were constructed from recently published high-resolution data on forest clearing. For 4,028 parks, panel estimation based on a variety of park characteristics was conducted to test if deforestation is lower in protected areas because of their protected status, or if other factors explain the difference. For a sample of 726 parks established since 2002, a test also was conducted to investigate the effect of park establishment on protection. The findings suggest park size, national park status, and management by indigenous people all have significant association with effective protection across regions. For the Asia/Pacific region, the test offers compelling evidence that park establishment has a near-immediate and powerful effect.

This paper is a product of the Computational Tools Team and Environment and Energy Team, Development Research Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at sdasgupta@worldbank.org.

Protected Areas and Deforestation: New Results from High Resolution Panel Data

Brian Blankespoor[1], Susmita Dasgupta, David Wheeler

Keywords: Protected Area, Deforestation
JEL Classification: Q23, Q57

This research was funded by the Knowledge for Change Program.

[1] Authors' names in alphabetical order. The authors are respectively Environment Specialist, Development Research Group, World Bank; Lead Environmental Economist, Development Research Group, World Bank; and Senior Fellow, World Resources Institute.

We would like to extend our special thanks to Valerie Hickey for her useful comments and suggestions. We are also thankful to Drona Raj Chimire, Rajesh Koirala, Bunlong Leng, William B. Magrath, Lan Thi Thu Nguyen, Viengkeo Phetnavongxay and Jack Tordoff for their help with the data.

1. Introduction

Many country studies have found that forest clearing is lower in protected areas. To illustrate the number and country range of such studies, we include the near-exhaustive bibliography of Geldmann et al (2013) and Nelson and Chomitz (2011) in the references for this paper. Most studies have tested the effects of protection status in regressions that include other determinants of forest clearing (Table S5 in Geldmann et al 2013). More sophisticated tests (e.g. Nelson and Chomitz, 2011, Joppa and Pfaff 2011; Gaveau et al 2009, Andam et al. 2008) have matched pairs of protected and unprotected areas that are similar in characteristics relevant for deforestation analysis. Although these studies have produced many useful insights, the scarcity of reliable time series data on deforestation has forced them all to take a cross-sectional approach. Without studies that measure deforestation before and after protection, the basic question of causality remains: Is deforestation lower in protected areas because of their protected status, or do other factors explain the difference?

A theoretically-appropriate test of protection would resemble quasi-experiments that have been performed in fields where data have been more plentiful. It would require observations on changes in protected areas and comparable non-protected areas, both before and after the establishment of legal protection. Such a study could employ a spatial panel of high-resolution data that permits measurement of forest clearing ex ante and ex post, with observations inside and outside of park boundaries in contiguous zones that are sufficiently narrow (and therefore indistinguishable on locational grounds) for near-precise matching to be achieved.

With the recent publication of global forest clearing data at 30 m resolution by Hansen~~,~~ et al. (2013), such quasi-experiments are now possible. The Hansen data identify 30 m cells as forested or cleared in every year from 2001 to 2012. This paper mobilizes the Hansen data to estimate annual deforestation rates for contiguous zones that straddle park boundaries for over 4,000 protected areas in 64 tropical forest countries. We calculate the ratio of deforestation rates outside and inside the boundaries of each park in each year. We adopt this ratio as our measure of protection effectiveness and use panel regression techniques to estimate the protection impacts of many park characteristics, including legal establishment dates.[2]

The remainder of the paper is organized as follows. Section 2 describes our database, while Section 3 explains the computation of outside/inside deforestation ratios. We present out results in Section 4, along with a discussion of the potential implications. Section 5 summarizes and concludes the paper.

2. Database Construction

The database for this exercise has four main components: 30 m forest clearing data from Hansen et al. (2013);[3] the World Database on Protected Areas (WDPA);[4] a shapefile identifying tropical forest areas, drawn from Hansen et al. (2003); and the database of Global Administrative Areas Version 2.0 maintained by GADM.org.[5]

2.1 Forest clearing data

The Hansen 30 m data are downloadable as a large set of tiff panels that cover all forested areas of the globe. This paper uses the panels that cover the pan-tropics. For each 30 m pixel where forest clearing is estimated to have occurred between 2000 and 2012, the pixel entry is the final two digits of the year with the most clearing. To make this exercise tractable (the pixel-level

[2] This paper focuses on forest cover loss, but we recognize that these are not the only measures for assessing conservation effectiveness. For example, we did not address degradation of forest in this paper.
[3] Available online at http://www.earthenginepartners.appspot.com/science-2013-global-forest/download.html.
[4] Available online at http://www.protectedplanet.net/.
[5] Available online at http://www.gadm.org/. Accessed 2014-03

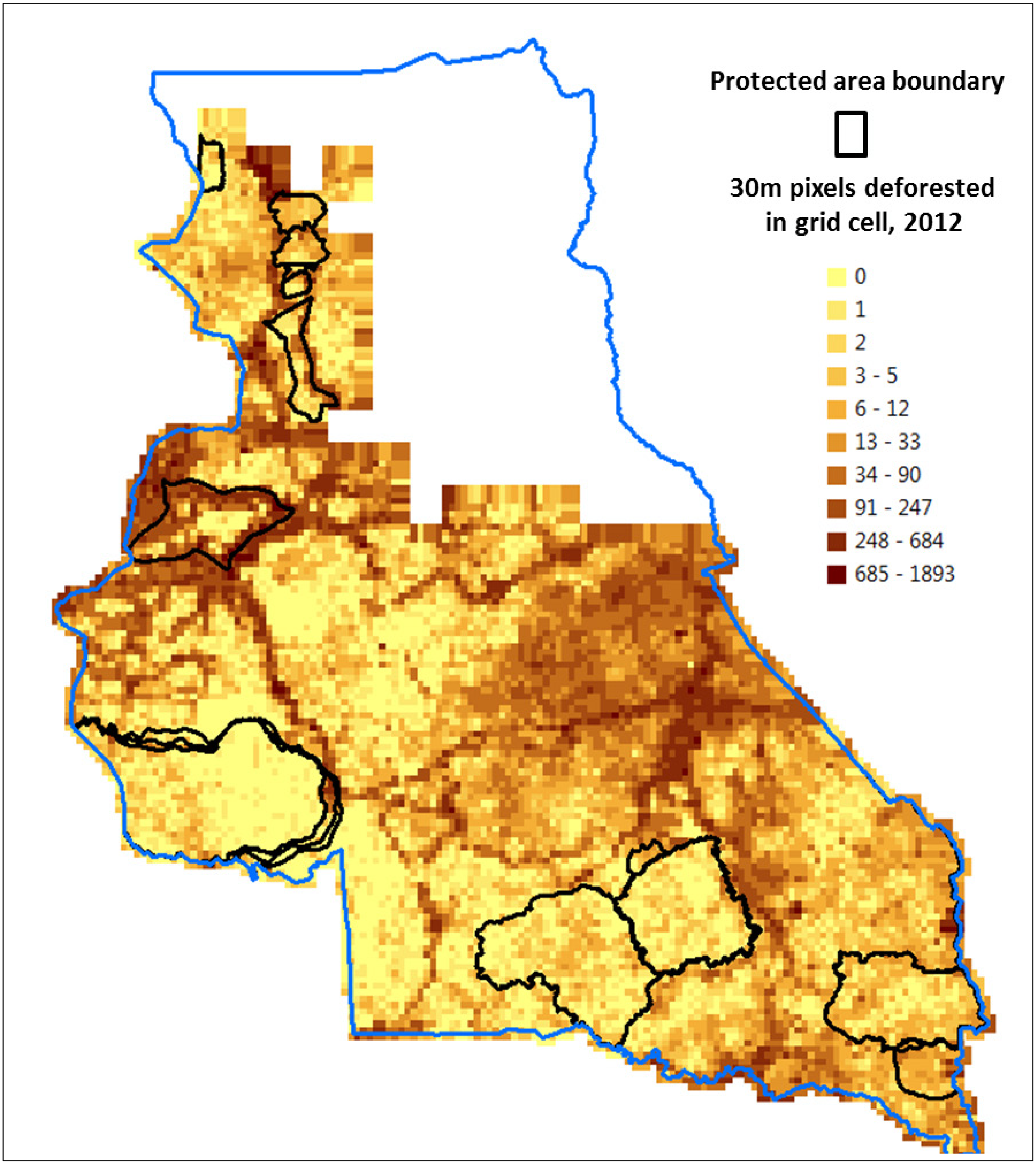
database is enormous), we have developed a routine in R that aggregates pixel counts by year for grid cells that are .0243 decimal degrees on a side. This translates to side dimensions of 2.7 kilometers at the equator, so each grid cell contains a maximum of 8,100 Hansen pixels. We code pixels by year: 1 if most of the clearing occurred in that year and 0 otherwise. Figure 1 illustrates the resolution of the grid-scale data in Est Province, Cameroon, with an overlay for protected areas. Substantial variation in forest clearing is apparent across protected areas, both inside and outside of park boundaries.

Using ArcGIS 10, we convert Hansen grid-scale rasters to point files (counts register at grid centroids) and intersect the point files with tropical forest area shapefiles and level-one administrative boundary files from GADM.org. We export the results to text files for operations in Stata that will be explained in the next section. We also export the intersections of Hansen point files with boundary files for protected areas and level-one administrative areas.

2.2 Protected areas

The core exercise for this paper is construction of zones that straddle the borders of individual protected areas. The supporting database is constructed in three steps. (1) We extract tropical forest protected areas from the WDPA to create shapefiles for the Asia/Pacific region (including parts of Australia), Africa and the Latin America/Caribbean region (including southern Florida in the US). (2) We convert the polygons for individual parks to boundary point files, labeling each boundary point with the park's WDPA ID number. (3) We intersect the point files with level-one administrative boundary files and export the results to text files for further operations in Stata.

Figure 1: Illustrative Example: Est Province, Cameroon: clearing in forested areas, 2012



3. Computations

Stata operations begin with three datasets for Africa, Asia/Pacific and Latin America/Caribbean (LAC): (1) the regional Hansen grid-scale point files for 2001-2012, with each point identified by latitude, longitude, country and level-one administrative unit; (2) the Hansen point files for protected areas, with each point identified by latitude, longitude, WDPA ID number, and a unit entry that identifies it as inside the identified park; (3) the park boundary point files, with each point identified by latitude, longitude and WDPA ID number.

3.1 Boundary zones

In the first computation step, we merge the point-level information in the two Hansen files by latitude and longitude. This enables separation of the merged file into points that are inside protected areas (identified by the parks file) and outside points (all the others). Then we use the Stata routine geonear to identify the point in the park boundary file that is closest to each point in the Hansen file. Geonear also computes the distance from the Hansen point to the closest boundary point. To keep the potentially-massive geometric calculations tractable, we use a looping routine that applies geonear sequentially to the point files for each level-one administrative unit.

After completing the calculation loops, we combine the level-one results into regional Hansen point files, where each point registers the annual grid cell Hansen pixel count for 2001-2012 and identification by country, level-one administrative unit, inside/outside status (relative to park boundaries), the park ID number of the closest park boundary point, the distance to that point, and the characteristics of the park (e.g., name, designated status, establishment year). The database offers complete flexibility for computation of outside/inside deforestation ratios, since the distance measures for individual points inside and outside of park boundaries permit creation of boundary zones of arbitrary size. For this exercise, we use a zonal width of 10 km.[6]

3.2 Zonal deforestation rates

We compute mean annual Hansen pixel counts per grid cell, within 10 km zones inside and outside of park boundaries. Mean counts are equivalent to deforestation rates, since the Hansen grid cells have a uniform size (.0243 decimal degrees). In the final step, we compute the ratio of outside to inside mean pixel counts.

A complication is introduced by the possibility of differential representation for inside and outside cells. If all protected areas were separated by distances greater than 10 km, this would not be a problem because each section of the within-park zone would have a corresponding section in the outside zone. However, some parks abut or are separated by fewer than 10 km, so intersection of their outside zones prevents full outside representation for either park. Even where proximity restricts outside representation, or where inside and outside grid cells are limited by small park size, our computations draw on huge samples because each grid cell summarizes the information in 8,100 30 m Hansen pixels.

4. Statistical Analysis

Using the methodology described in Section 3, we compute annual outside/inside deforestation ratios for 4,028 parks in 64 countries: 20 in Africa, 23 in LAC, and 21 in Asia/Pacific. Table 1 tabulates our sample parks by region and country.

[6] We recognize that the area inside a protected area/ park and its surrounding area do not always have similar environmental conditions as pointed out by Mas 2005; however thorough investigation of all relevant characteristics of 4,028 parks in 64 countries and their surrounding areas was beyond the scope of our analysis. Instead, we used 10-km area surrounding park boundaries for testing the effectiveness of the parks .Use of 10-km buffer is a common practice in the literature. For example, see Pfeifer et al. 2012, Gaveau et al. 2009, Bruner et al. 2001.

Table 1: Total protected areas, by region and country

Africa	No.	Latin America / Caribbean	No.	Asia / Pacific	No.	Other	No.
Burundi	3	Argentina	34	Bhutan	3	Australia	48
Cameroon	73	Belize	34	Brunei	16	United States	3
Central African Republic	7	Bolivia	31	Cambodia	18		
Democratic Republic of the Congo	27	Brazil	909	China	258		
Equatorial Guinea	5	Colombia	318	Hong Kong SAR, China	5		
Gabon	15	Costa Rica	68	India	157		
Ghana	166	Cuba	34	Indonesia	236		
Guinea	13	Dominican Republic	27	Lao PDR	26		
Kenya	65	Ecuador	21	Malaysia	108		
Liberia	14	El Salvador	3	Myanmar	38		
Madagascar	40	French Guiana	7	Nepal	9		
Mayotte	1	Guatemala	66	New Caledonia	12		
Nigeria	129	Guyana	5	Papua New Guinea	24		
Republic of Congo	5	Honduras	23	Philippines	97		
Rwanda	5	Jamaica	25	Singapore	1		
Sao Tome and Principe	2	Mexico	90	Sri Lanka	75		
Sierra Leone	24	Nicaragua	20	Taiwan, ~~(~~China~~)~~	11		
Tanzania	86	Panama	30	Thailand	149		
Togo	8	Paraguay	15	Vanuatu	5		
Uganda	50	Peru	75	Vietnam	90		
		Suriname	12				
		República Bolivariana de Venezuela	54				

4.1 Descriptive Statistics

Table 2 introduces the data by presenting median outside/inside ratios by region and year, categorized by percentile and according to whether a park achieved protected status before 2000, or during the period since.

Although the three regions and 64 countries are quite diverse, we find strikingly common patterns in Table 2. As the 12-year averages show most clearly, each region's 25th percentile parks have outside/inside ratios that are generally less than one. This means that in all three regions, at least 25% of the parks are consistently offering no protection at all (or at least protection as we measure it). The median (50th percentile) statistics, on the other hand, tell a more hopeful story. In each region, protection appears sufficient in the median park for the outside/inside ratio to be greater than 1.5:1 in all cases except one. And parks at the 75th percentile offer very substantial protection in all regions, with ratios of 3:1 or greater.

Our results for parks established during the 2000s and previous periods reveal some interesting differences. This is particularly true for Africa, where typical median ratios rise sharply for parks established more recently: from 0.60 to 1.10 at 25%; 1.36 to 2.42 at the median; and 2.96 to 5.28 at 75%. These results may reflect recent progress in governance, as well as more emphasis on cost-effectiveness by conservation aid donors. The converse is true for LAC, with lower ratios for more recently-established parks in all three percentile categories. These results may reflect recent progress in governance, as well as more emphasis on cost-effectiveness by conservation aid donors. Asia/Pacific is mixed, with approximate stability in the 25th and 50th percentiles, but a somewhat higher 75th percentile ratio in the 2000s.

Table 2: Median outside/inside deforestation ratios for protected areas by region, 2001-2012

Region	Pct	Start Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mean	Mean, 2001-06	Mean, 2007-12
Africa	25	Before 2001	0.64	0.62	0.61	0.50	0.65	0.59	0.57	0.67	0.64	0.56	0.61	0.57	0.60	0.60	0.60
		2001-2012	1.31	1.09	1.09	0.87	0.92	1.06	0.92	1.34	1.31	1.08	1.11	1.08	1.10	1.06	1.14
	50	Before 2001	1.29	1.34	1.27	1.25	1.47	1.43	1.38	1.39	1.52	1.36	1.30	1.29	1.36	1.34	1.37
		2001-2012	2.53	2.77	2.36	2.21	2.08	2.44	2.49	2.54	2.30	1.99	2.79	2.53	2.42	2.40	2.44
	75	Before 2001	3.00	3.10	2.91	2.70	3.00	3.30	2.99	2.93	3.23	2.72	2.74	2.90	2.96	3.00	2.92
		2001-2012	6.12	7.36	4.84	4.12	4.71	5.95	5.70	5.53	4.51	4.16	5.65	4.72	5.28	5.52	5.05
Latin America / Caribbean	25	Before 2001	0.88	0.87	0.88	0.87	0.80	0.87	0.76	0.80	0.88	0.81	0.78	0.86	0.84	0.86	0.82
		2001-2012	0.76	0.75	0.70	0.75	0.72	0.74	0.80	0.76	0.77	0.75	0.76	0.84	0.76	0.74	0.78
	50	Before 2001	2.14	2.00	1.93	2.00	1.89	2.02	1.99	2.02	1.85	1.79	1.78	1.75	1.93	2.00	1.86
		2001-2012	1.90	1.88	1.80	1.87	1.73	1.77	1.97	1.80	1.70	1.71	1.78	1.77	1.81	1.83	1.79
	75	Before 2001	5.73	5.66	5.83	5.73	5.75	5.85	5.59	5.52	5.26	5.01	4.75	4.26	5.41	5.76	5.07
		2001-2012	4.65	5.56	4.90	4.94	4.66	4.90	5.50	5.06	4.43	4.46	4.51	4.11	4.81	4.94	4.68
Asia/Pacific	25	Before 2001	0.79	0.81	0.75	0.81	0.79	0.88	0.83	0.85	0.90	0.87	0.92	0.92	0.84	0.81	0.88
		2001-2012	0.67	0.78	0.91	0.83	0.77	0.75	0.77	0.75	0.94	0.69	0.98	0.76	0.80	0.79	0.82
	50	Before 2001	1.71	1.72	1.61	1.70	1.62	1.75	1.73	1.80	1.80	1.81	1.80	1.77	1.74	1.69	1.79
		2001-2012	2.12	1.59	1.88	1.78	1.71	1.95	1.75	1.85	1.84	1.87	2.40	1.80	1.88	1.84	1.92
	75	Before 2001	3.91	4.05	3.77	3.73	3.54	3.85	3.78	3.91	4.09	3.92	4.04	3.82	3.87	3.81	3.93
		2001-2012	3.76	4.71	5.09	4.14	3.97	4.50	4.84	5.58	4.42	3.95	4.75	4.24	4.50	4.36	4.63

To assess changes during the past decade, we subdivide the data into two periods and compute averages for each period. As Table 2 shows, we find little evidence of systematic improvement or deterioration, although some of the differences might be significant in a large-sample statistical analysis.

4.2 Regression Results

Our regression exercise in this paper has two parts. First, we use the new database to test the association between effective protection and a variety of park characteristics in Asia/Pacific, Africa and LAC. We perform panel estimates by random effects, because we are primarily interested in the cross-sectional characteristics of parks. Our second exercise focuses on time series tests of the impact of park establishment on deforestation. For these tests, we estimate by fixed effects. Inspection of the data reveals that the outside/inside ratio is highly skewed, but its logarithm has a near-normal distribution. Accordingly, we use log ratios in our regressions.

4.2.1 Park Characteristics and Forest Protection

The Hansen data provide consistent measurement of global tropical forest clearing at high resolution, so they offer an unprecedented opportunity for investigating the association between forest protection and park characteristics. In this section, we mobilize the WDPA database to test a wide variety of characteristics related to park size, age, IUCN status, management and legal status. We also incorporate annual dummy variables for 2001-2012 and our park establishment test variable, whose value is 0 for years prior to park establishment and 1 thereafter. We regard this exercise -as a weak test of park establishment, since it does not control explicitly for time intervals before and after establishment. We will introduce such controls in the next section, which applies a strong test using fixed effects estimation.

Table 3 presents separate random effects results for Asia/Pacific, LAC and Africa. We use the log of the outside/inside ratio as the dependent variable. Our independent variables include the park establishment test variable, the log of park area, and dummy variables that identify decade of establishment, all seven IUCN park categories, eleven management categories, and three legal status categories. The Appendix describes the regression variables in more detail. For Asia/Pacific, we also test for the effect of species charisma by including a dummy variable whose value is 1 if a park overlaps with IUCN's current estimate of tiger habitat and 0 otherwise.

Collinearity has forced the exclusion of some variables in Asia/Pacific and Africa. In the following discussion, we treat the outside/inside ratio and degree of protection as synonymous. Our results suggest that only a few of the 27 tested variables have highly-significant associations with forest protection, and even fewer have consistently-significant associations across regions. The park establishment test variable fails our weak test in all three regions: Estimated coefficients are consistently positive (implying that park establishment raises the outside/inside deforestation ratio), but they all fail to meet classical significance tests. In contrast, park size has positive and highly-significant effects on protection in all three regions, with the same order of magnitude. This may reflect either economies of scale in protection or the greater political visibility and/or importance of larger parks.

Our results for establishment decades are uniformly weak for Asia/Pacific, which implies that parks established since 1980 are no more effectively protected than parks established during prior decades. The LAC result is mixed, with a significant result for parks established in the 1980s. The results are considerably stronger in Africa; parks established since 1980 achieve greater protection than their predecessors, and parks established since 2000 have the strongest protective advantage.

Table 3: Park Characteristics and Forest Protection, 2001-2012: Random Effects Estimates Variable definitions in the Appendix

Dependent Variable: Log Outside/Inside Deforestation Ratio

	Asia/Pacific	Latin America/ Caribbean	Africa
Park Establishment Test Statistic	0.038	0.032	0.005
	(0.51)	(1.11)	(0.08)
Log Park Area	0.059	0.035	0.045
	(3.67)**	(2.85)**	(2.33)*
Establishment Date			
1980-1989	-0.005	0.266	0.682
	(0.08)	(2.70)**	(2.47)*
1990-1999	0.087	0.143	0.516
	(1.11)	(1.69)	(2.18)*
2000-2012	0.143	0.111	0.703
	(1.10)	(1.39)	(3.92)**
IUCN Status			
Ia: Strict Nature Reserve	0.559	0.606	0.101
	(4.74)**	(3.68)**	(0.18)
Ib: Wilderness Area	1.033	-0.400	0.234
	(1.53)	(0.66)	(0.53)
II: National Park	0.467	0.504	0.755
	(4.36)**	(4.81)**	(4.66)**
III: Natural Monument	0.125	0.420	0.779
	(0.29)	(1.69)	(1.71)
IV: Habitat Management Area	-0.094	0.381	0.294
	(0.87)	(2.59)**	(2.06)*
V: Protected Landscape	0.045	-0.184	
	(0.43)	(1.36)	
VI: Sustainable Resource Use	0.096	0.329	-0.053
	(0.78)	(3.29)**	(0.20)
WWF/IUCN Tiger Landscape	0.162		
	(2.31)*		

Management	Asia/ Pacific	Latin America/ Caribbean	Africa
National Ministry	-0.114	0.012	-0.203
	(1.32)	(0.13)	(1.59)
Sub-National Ministry	0.523	0.055	-1.735
	(5.62)**	(0.54)	(1.58)
Delegated by Government		-0.825	0.458
		(1.17)	(0.63)
Collaborative	-1.745	0.126	-1.432
	(1.86)	(0.29)	(1.85)
Joint	0.108	0.696	
	(0.11)	(1.78)	
Private Governance		0.327	-0.369
		(0.91)	(0.27)
Individual Landowners	-0.899	0.111	
	(1.52)	(0.25)	
Non-Profit Organizations		-0.103	
		(0.20)	
For-Profit Organizations		0.261	
		(0.51)	
Indigenous Peoples	0.678	0.372	
	(2.70)**	(4.18)**	
Local Communities		0.152	0.293
		(0.71)	(0.69)
Park Status			
Designated	1.455	-0.225	0.106
	(1.44)	(1.48)	(0.40)
Inscribed	1.536	0.227	-0.480
	(1.47)	(0.55)	(1.00)
Proposed	1.485	-0.625	0.170
	(1.47)	(3.41)**	(0.65)
Constant	-0.840	0.883	0.380
	(0.83)	(5.03)**	(1.24)
R^2	0.06	0.05	0.07
Observations	14,761	20,328	7,875
Number of Parks	1,359	1,887	729

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Among the IUCN status variables, the results for national parks are the most consistent and noteworthy. Across Africa, LAC and Asia/Pacific, national parks achieve greater protection, and the effect has similar orders of magnitude in all three regions. Strict nature reserves benefit significantly from stronger protection in Asia/Pacific and LAC, but not in Africa. On the other hand, habitat management areas are more effectively protected in LAC and Africa, but not in Asia/Pacific. Parks that are zoned for sustainable natural resource use are significantly better protected in LAC, but not in the other two regions.[7] In Asia/Pacific, we have apparent confirmation of the species charisma effect: The presence of tiger habitat in parks has a positive, significant impact on the effectiveness of protection.[8] This may well reflect additional funding by domestic and international conservation donors, as well as greater administrative focus on monitoring and enforcement within park boundaries.

In the literature, there is a disagreement on the "best practices" for forest conservation (for example, Shahabuddin and Roa 2010 and Wilshusen et al 2002). Our results for eleven park management categories are almost entirely insignificant, with one stellar exception: Management by indigenous peoples has large, highly-significant positive effects on protection in Asia/Pacific and Latin America. We have no result for Africa, where collinearity has forced exclusion of this variable. Only one other management variable has significance in any region: Management by sub-national ministries makes a large, positive, highly-significant contribution to protection in Asia/Pacific. In light of Indonesia's sizable representation in the sample, this provides at least a hopeful suggestion that Indonesia's recent emphasis on administrative decentralization has yielded positive results in this domain.

[7] High variability of effectiveness between Protected Area categories has been documented for East Africa's evergreen forests also by Pfeifer et al. 2012. Three global studies conducted by Joppa and Pfaff, 2011, Scharelmann et al. 2010, and Nelson and Chomitz, 2009 also highlighted increase in effectiveness of Protected Area with stricter protection as implied by the IUCN categories (Geldmann et al. 2013).

[8] For tiger habitats see Forrest et al. (2011)

At this point, it is worth reiterating that our results suggest insignificance for several management modes that figure prominently in discussions of forest governance and protection. These include management by national ministries, individual landowners, profit-making enterprises, local non-indigenous communities, non-profit organizations, and private entities. [9]

Our results are also sparse for legally-defined status -- designated, inscribed or proposed. Only the latter has any significance, and that is in one region: LAC, where protection is much lower in parks that have been proposed but not yet legally designated.

4.2.2 Testing the Impact of Park Establishment

Since our database identifies each park by start year, it permits us to perform quasi-experiments to test the effect of park establishment on deforestation for protected areas that have been established since 2002. We produce our estimation sample by extracting these 726 parks. Then we use statistical analysis to pose the question: Has acquisition of official protection status changed the outside/inside ratio significantly? If so, we have highly suggestive evidence that official protection has actually made a difference. If not, then we can tentatively conclude that the outside/inside ratios we observe are principally reflections of other factors. We should note that these factors may also be related to protection, which could be provided by a host of local and/or informal arrangements that are not reflected in official park establishment years. Advance notice of establishment may also create a perverse effect, in which clearing accelerates in an area before official protection begins. All things considered, our results might best be interpreted as measuring the net impact of enhanced effectiveness ex post vs. anticipatory acceleration of clearing ex ante.

[9] For example, see the metaanalysis conducted by Geldmann et a, 2013..

A problem for estimation in this context is the variable length of comparison periods imposed by variable park establishment dates and fixed bounding dates in the Hansen deforestation data. To accommodate this, we perform successive experiments for parks with different start dates. We are not likely to produce robust results in such quasi-experiments with very short observation periods either before or after establishment dates. Accordingly, we adopt two years as the minimum standard and perform successive estimations for parks with start dates from 2002 to 2009. We estimate the panel by fixed effects, which enables us to focus on the time series result of interest. Since we do not need multivariate controls in this case, our statistical approach is simple and straightforward. For each park, we define a dummy variable whose value is 0 for the period from 2000 to its year of establishment, and 1 for later periods. For example, the test variable for a park established in 2004 is 0 for 2001-2004 and 1 for 2005-2012. Our regressions use the dummy variable to test whether the outside/inside ratio is significantly different after the park has been established. We also use annual dummy variables for 2002-2012 to control for general fluctuations that might confound the measured effect of park establishment (the first year is excluded to avoid perfect collinearity).

Table 4 presents results for rolling samples in Africa, LAC and Asia/Pacific. For each region, each row presents results for parks established in the base year or later. The table includes four columns for each variable: the number of observations used for estimation; the estimated log of the outside/inside ratio prior to park establishment; the estimated impact of park establishment; and the outside/inside ratio prior to park establishment (this is the antilog of column 2, included to show typical magnitudes of outside/inside ratios across regions and over time).

Our estimates for outside/inside ratios are quite strong and consistent, both across regions and for different temporal samples within regions. The results in the second and fourth columns for each region are highly significant and suggest typical outside/inside ratios of two or higher. To be clear, the estimation samples for this exercise include only parks established since 2000, and the results in the second and fourth columns are estimated outside/inside ratios during the period *prior to legal establishment.*

Our estimates of establishment effects are quite consistent within regions, but highly-varied across regions. In Africa and LAC, we see no evidence that legal establishment has any effect: The ex-post outside/inside deforestation ratio is not significantly different from the ex-ante ratio.

In Asia/Pacific, however, the situation appears very different. With the exception of what looks like a strange sample artifact for parks established after 2009, the impact of legal establishment is very large, positive, and highly significant. For Asia/Pacific, this offers compelling evidence that park establishment has a near-immediate and powerful effect.

To summarize, using the interpretive framework that we have suggested, our fixed-effects results suggest a rough balance between ex-post effectiveness and ex-ante anticipatory acceleration of deforestation in Africa and LAC. In Asia/Pacific, on the other hand, the ex-post effect appears clearly dominant. We acknowledge that other interpretations are possible; important roles may well be played by unobserved variables. Our test is confined to published establishment dates for parks, and it is quite possible that many have enjoyed de facto protected status prior to their public establishment. The underlying sources of protection may be social, economic, institutional and political arrangements that are local, contextual and largely unobservable to outsiders. It is also entirely possible that the time interval available for this study is simply too short to judge long-term effectiveness. The issue should be revisited as the Hansen team and other groups continue to extend high-resolution estimates of deforestation both forward and backward in time.

Table 4: Effect of Park Establishment on Deforestation

Dependent variable: Log Outside/Inside Ratio

	Africa				Latin America/Caribbean				Asia/Pacific			
Base Year	Obs	Log Outside/ Inside Ratio	Test Variable	Outside/ Inside Ratio	Obs	Log Outside/ Inside Ratio	Test Variable	Outside/ Inside Ratio	Obs	Log Outside/ Inside Ratio	Test Variable	Outside/ Inside Ratio
2002	887	.945**	-0.029	2.574**	5,901	.805**	-0.038	2.238**	717	.741**	.449**	2.097**
2003	731	.853**	0.024	2.346**	5,508	.817**	-0.022	2.263**	655	.743**	.467**	2.101**
2004	459	.882**	0.154	2.415**	4,816	.804**	-0.040	2.235**	559	.769**	.689**	2.157**
2005	391	.825**	0.157	2.281**	4,281	.806**	-0.073	2.239**	484	.864**	.934**	2.372**
2006	327	.916**	0.111	2.499**	3,527	.817**	-0.070	2.263**	465	.867**	.844**	2.379**
2007	227	1.112**	0.026	3.042**	2,800	.755**	-0.132	2.128**	412	.965**	.815*	2.625**
2008	192	1.039**	0.179	2.827**	1,908	.699**	-0.012	2.011**	351	.959**	.997**	2.61**
2009	156	1.19**	0.106	3.288**	1,107	.614**	-0.063	1.848**	224	1.09**	0.04	2.974**

* Significant at 5%
** Significant at 1%

5. Summary and Conclusions

In this paper, we have used high-resolution data from Hansen et al (2013) to take a new look at the effectiveness of protected areas in slowing tropical forest clearing. Our measure of effective protection for each park is the ratio of deforestation rates in boundary zones that extend 10 km outside and inside the park's boundary. We compute deforestation rates from data at 30 m resolution for 4,028 parks in 64 countries in Asia/Pacific, Africa and Latin America. For each park, we construct an annual time series of outside/inside rates for the period 2001-2012.

For estimation work, we join our Hansen panel to extensive data on park characteristics from the WDPA database. We use two sets of panel estimates to test associations between park characteristics and our measure of protection. In the first exercise, we use random effects to test the effect of parks' age, size, IUCN status, management mode and legal status on forest protection. We find very high significance for some of these variables, but no significance for many of them. Particularly important variables in this context are park size, national park status, and management by indigenous peoples. They all have large, positive, highly-significant associations with effective protection across regions. In a supplementary test, we also find a significant, positive impact for "species charisma" in Asia/Pacific, embodied in higher effective protection for parks that include tiger habitat.

In the second exercise, we use fixed-effects estimation to focus on the effect of park establishment on protection. Our estimation work is confined to the period after 2000, since that is the temporal span of the Hansen data. We extract protected areas established since 2002 from the database, yielding a sample of 726 parks. Then we test establishment effectiveness with a variable for each park whose value is 0 for the period from 2001 until the establishment year and 1 thereafter. Our formal test is panel regression by fixed effects for a model with a constant term and the establishment test variable, plus annual dummies to control for other exogenous changes since 2000. We find a positive, highly significant effect for establishment only in Asia/Pacific. We tentatively conclude that our results reflect the net balance between two forces: potentially-enhanced effectiveness ex post, after a park is formally established, and accelerated deforestation ex ante, as forest proprietors anticipate the effect of legal closure. Interpreted in this light, our results suggest that the two forces are roughly balanced in Africa and Latin America/Caribbean, but that ex-post effectiveness dominates in Asia/Pacific. We acknowledge that other forces may well be in play. Further insight will undoubtedly be gained as the Hansen team and others continue to extend the temporal range of high-resolution deforestation measures.

References

J. L. Forrest, B. Bomhard, A. Budiman, L. Coad, N. Cox, E. Dinerstein, D. Hammer, C. Huang, et al. (2011) Single-species conservation in a multiple-use landscape: current protection of the tiger range. *Animal Conservation,* 14**:** 283 - 294.

Geldmann, J., M. Barnes, L. Coad, I. D. Craigie, M. Hockings, and N. D. Burgess. (2013) Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. *Biological Conservation,* 161**:** 230-238.

Hansen, M.C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice and J. R. G. Townshend. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science,* 342(6160): 850-853.

Hansen M, et al. (2003) Global percent tree cover at a spatial resolution of 500 meters: First results of the MODIS vegetation continuous fields algorithm. *Earth Interact,* 7:1–15. Available at http://ams.allenpress.com/archive/1087–3562/7/10/pdf/i1087–3562-7–10-1.pdf.

Joppa L, Pfaff A. (2011) Reassessing the forest impacts of protection. *Annals of the New York Academy of Sciences,* 1185: 135–149.

Nagendra H. (2008) Do Parks Work? Impact of Protected Areas on Land Cover Clearing. *AMBIO: A Journal of the Human Environment*, 37: 330–337.

Naughton-Treves L, Holland MB, Brandon K. (2005) The Role of Protected Areas in Conserving Biodiversity and Sustaining Local Livelihoods. *Annual Review of Environment and Resources*, 30: 219–252.

Nelson, Andrew and Kenneth M. Chomitz. (2011) Effectiveness of Strict vs. Multiple Use Protected Areas in Reducing Tropical Forest Fires: A Global Analysis Using Matching Methods. *PLoS ONE*, 6(8): e22722.

Pfeifer, M., N. D. Burgess, R. D. Swetnam, P. J. Platts, S. Willcock, and R. Marchant. (2012) Protected Areas: Mixed Success in Conserving East Africa's Evergreen Forests. *PLoS ONE,* 7**:** e39337.

Porter-Bolland, L., E. A. Ellis, M. R. Guariguata, I. Ruiz-Mallén, S. Negrete-Yankelevich, and V. Reyes-García. (2012) Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. *Forest Ecology and Management,* 268**:** 6-17.

Scharlemann, J. r. P., V. Kapos, A. Campbell, I. Lysenko, N. D. Burgess, M. C. Hansen, H. K. Gibbs, B. Dickson, et al. (2010) Securing tropical forest carbon: the contribution of protected areas to REDD. *Oryx,* 44**:** 352-357.

Country Studies

Belize

Chomitz KM, Gray DA. (1996) Roads, Land Use, and Deforestation: A Spatial Model Applied to Belize. *The World Bank Economic Review*, 10: 487–512.

Bolivia

Mertens, B., D. Kaimowitz, A. Puntodewo, J. Vanclay, and P. Mendez. (2004) Modeling deforestation at distinct geographic scales and time periods in Santa Cruz, Bolivia. *International Regional Science Review,* 27**:** 271-296.

Brazil

Chomitz KM, Thomas TS. (2003) Determinants of Land Use in Amazônia: A Fine-Scale Spatial Analysis. *American Journal of Agricultural Economics*, 85: 1016–1028.

Soares-Filho B, Moutinho P, Nepstad D, Anderson A, Rodrigues H, et al. (2010) Role of Brazilian Amazon protected areas in climate change mitigation. *Proceedings of the National Academy of Sciences*, 107: 10821–10826.

Adeney JM, Christensen NL Jr, Pimm SL. (2009) Reserves Protect against Deforestation Fires in the Amazon. *PLoS ONE*, 4: e5014.

Nepstad D, Schwartzman S, Bamberger B, Santilli M, Ray D, et al. (2006) Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands. *Conservation Biology*, 20: 65–73.

China

Liu, J., M. Linderman, Z. Ouyang, L. An, J. Yang, and H. Zhang. (2001) Ecological Degradation in Protected Areas: The Case of Wolong Nature Reserve for Giant Pandas. *Science,* 292**:** 98-101.

Columbia

Armenteras, D., G. Rudas, N. Rodriguez, S. Sua, and M. Romero. (2006) Patterns and causes of deforestation in the Colombian Amazon. *Ecological Indicators,* 6**:** 353-368.

Costa Rica

Arroyo-Mora, J. P., G. A. Sánchez-Azofeifa, B. Rivard, J. C. Calvo, and D. H. Janzen. (2005) Dynamics in landscape structure and composition for the Chorotega region, Costa Rica from 1960 to 2000. *Agriculture, Ecosystems & Environment,* 106**:** 27-39.

Arturo Sánchez-Azofeifa G, Daily GC, Pfaff ASP, Busch C. (2003) Integrity and isolation of Costa Rica's national parks and biological reserves: examining the dynamics of land-cover change. *Biological Conservation*, 109: 123–135.

Pfaff A, Robalino J, Sanchez-Azofeifa GA, Andam K, Ferraro PJ. (2009) Park Location Affects Forest Protection: Land Characteristics Cause Differences in Park Impacts across Costa Rica. *The BE Journal of Economic Analysis & Policy*, 9: 26.

Andam KS, Ferraro PJ, Pfaff A, Sanchez-Azofeifa GA, Robalino JA. (2008) Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences*, 105: 16089–16094.

Sanchez-Azofeifa, G. A., B. Rivard, J. Calvo, and I. Moorthy. (2002) Dynamics of Tropical Deforestation around National Parks: Remote Sensing of Forest Change on the Osa Peninsula of Costa Rica. *Mountain Research and Development,* 22**:** 352-358.

Côte d'Ivoire

Chatelain, C., A. Bakayoko, P. Martin, and L. Gautier. (2010) Monitoring tropical forest fragmentation in the Zagné-Taï area (west of Taï National Park, Côte d'Ivoire). *Biodiversity and Conservation,* 19**:** 2405-2420.

Ecuador

Messina, J. P., S. J. Walsh, C. F. Mena, and P. L. Delamater. (2006) Land tenure and deforestation patterns in the Ecuadorian Amazon: Conflicts in land conservation in frontier settings. *Applied Geography,* 26**:** 113-128.

Ghana

Alo, C. A., and R. G. Pontius Jr. (2008) Identifying systematic land-cover transitions using remote sensing and GIS: the fate of forests inside and outside protected areas of Southwestern Ghana. *ENVIRONMENT AND PLANNING B PLANNING AND DESIGN,* 35**:** 280.

Guatemala

Bray, D. B., E. Duran, V. H. Ramos, J.-F. Mas, A. Velazquez, R. B. McNab, D. Barry, and J. Radachowsky. (2008) Tropical deforestation, community forests, and protected areas in the Maya Forest. *Ecology and Society,* 13**:** 56.

Hayes, D. J., S. A. Sader, and N. B. Schwartz. (2002) Analyzing a forest conversion history database to explore the spatial and temporal characteristics of land cover change in Guatemala's Maya Biosphere Reserve. *Landscape Ecology,* 17**:** 299-314.

Sader, S. A., D. J. Hayes, J. A. Hepinstall, M. Coan, and C. Soza. (2001) Forest change monitoring of a remote biosphere reserve. *International journal of Remote Sensing,* 22**:** 1937-1950.

Honduras

Southworth J, Nagendra H, Carlson LA, Tucker C. (2004) Assessing the impact of Celaque National Park on forest fragmentation in western Honduras. *Applied Geography,* 24: 303–322.

Indonesia

Curran LM, Trigg SN, McDonald AK, Astiani D, Hardiono YM, et al. (2004) Lowland Forest Loss in Protected Areas of Indonesian Borneo. *Science*, 303: 1000–1003.

Gaveau, D. L., H. Wandono, and F. Setiabudi. 2007. Three decades of deforestation in southwest Sumatra: Have protected areas halted forest loss and logging, and promoted re-growth? *Biological Conservation,* 134**:** 495-504.

Gaveau DLA, Epting J, Juhn D, Kanninen M, Leader-Williams N. (2009) The future of forests and orangutans (Pongo abelii) in Sumatra: predicting impacts of oil palm plantations, road construction, and mechanisms for reducing carbon emissions from deforestation. *Environmental Research Letters*, 4: 1–11.

Gaveau DLA, Linkie M, Suyadi , Levang P, Leader-Williams N. (2009) Three decades of deforestation in southwest Sumatra: Effects of coffee prices, law enforcement and rural poverty. *Biological Conservation*, 142: 597–605.

Gaveau DLA, Epting J, Lyne O, Linkie M, Kumara I, et al. (2009) Evaluating whether protected areas reduce tropical deforestation in Sumatra. *Journal of Biogeography*, 36: 2165–2175.

Kinnaird, M. F., E. W. Sanderson, T. G. O'Brien, H. T. Wibisono, and G. Woolmer. (2003) Deforestation Trends in a Tropical Landscape and Implications for Endangered Large Mammals. *Conservation Biology,* 17**:** 245-257.

Linkie, M., R. J. Smith, and N. Leader-Williams (2004) Mapping and predicting deforestation patterns in the lowlands of Sumatra. *Biodiversity & Conservation,* 13**:** 1809-1818.

Jamaica

Tole, L. (2002) Habitat loss and anthropogenic disturbance in Jamaica's Hellshire Hills area. *Biodiversity & Conservation,* 11**:** 575-598.

Kenya

Bleher, B., D. Uster, and T. Bergsdorf. (2006) Assessment of Threat Status and Management Effectiveness in Kakamega Forest, Kenya. *Biodiversity and Conservation,* 15**:** 1159-1177.

Mwangi, M. K., S. Butchart, F. Munyekenye, L. Bennun, M. Evans, L. Fishpool, E. Kanyanya, I. Madindou, et al. (2010) Tracking trends in key sites for biodiversity: a case study using Important Bird Areas in Kenya. *Bird Conservation International,* 20**:** 215-230.

Tabor, K., N. D. Burgess, B. P. Mbilinyi, J. J. Kashaigili, and M. K. Steininger. (2010) Forest and woodland cover and change in coastal Tanzania and Kenya, 1990 to 2000. *Journal of East African Natural History,* 99**:** 19-45.

Madagascar

Gorenflo LJ, Corson C, Chomitz KM, Harper G, Honzák M, et al. (2011) Exploring the Association Between People and Deforestation in Madagascar. In: Cincotta RP, Gorenflo LJ, editors. Human Population: Its Influences on Biological Diversity. Berlin: Springer. pp. 197–221.

Ingram, J. C., and T. P. Dawson. (2005) Technical Note: Inter‚Äêannual analysis of deforestation hotspots in Madagascar from high temporal resolution satellite observations. *International journal of Remote Sensing,* 26**:** 1447-1461.

Malawi

Abbot, J. I., and K. Homewood. (1999) A history of change: causes of miombo woodland decline in a protected area in Malawi. *Journal of Applied Ecology,* 36**:** 422-433.

México

Brower, L. P., G. Castilleja, A. Peralta, J. Lopez-Garcia, L. Bojorquez-Tapia, S. Diaz, D. Melgarejo, and M. Missrie. (2002) Quantitative changes in forest quality in a principal overwintering area of the monarch butterfly in Mexico, 1971-1999. *Conservation Biology,* 16**:** 346-359.

Chowdhury, R. R. (2006) Landscape change in the Calakmul Biosphere Reserve, Mexico: Modeling the driving forces of smallholder deforestation in land parcels. *Applied Geography,* 26**:** 129-152.

Ellis, E. A., and L. Porter-Bolland. (2008) Is community-based forest management more effective than protected areas?: A comparison of land use/land cover change in two neighboring study areas of the Central Yucatan Peninsula, Mexico. *Forest Ecology and Management,* 256**:** 1971-1983.

Mas, J.-f. (2005) Assessing protected area effectiveness using surrounding (buffer) areas environmentally similar to the target area. *Environmental monitoring and assessment,* 105**:** 69-80.

Mendoza, E., and R. Dirzo. (1999) Deforestation in Lacandonia (southeast Mexico): evidence for the declaration of the northernmost tropical hot-spot. *Biodiversity & Conservation,* 8**:** 1621-1641.

Myanmar

Songer, M., A. Myint, B. Senior, R. DeFries, and P. Leimgruber. (2008) Spatial and temporal deforestation dynamics in protected and unprotected dry forests: a case study from Myanmar (Burma). *Biodiversity and Conservation,* 18**:** 1001-1018.

Nepal

Nagendra, H., S. Pareeth, B. Sharma, C. M. Schweik, and K. R. Adhikari. (2007) Forest fragmentation and regrowth in an institutional mosaic of community, government and private ownership in Nepal. *Landscape Ecology,* 23**:** 41-54.

Nicarágua

Smith, R. J., R. D. J. Muir, M. J. Walpole, A. Blamford, and N. Leader-Williams. (2003) Governance and the loss of biodiversity. *Nature,* 426**:** 67.

Panamá

Nelson, G. C., V. Harris, and S. W. Stone. (2001) Deforestation, Land Use, and Property Rights: Empirical Evidence from Darien, Panama. *Land Economics,* 77**:** 187-205. DOI: http://le.uwpress.org/content/by/year

Oestreicher, J. S., K. Benessaiah, M. C. Ruiz-Jaen, S. Sloan, K. Turner, J. Pelletier, B. Guay, K. E. Clark, et al. (2009) Avoiding deforestation in Panamanian protected areas: An analysis of protection effectiveness and implications for reducing emissions from deforestation and forest degradation. *Global Environmental Change,* 19**:** 279-291.

Peru

Oliveira PJC, Asner GP, Knapp DE, Almeyda A, Galvan-Gildemeister R, et al. (2007) Land-Use Allocation Protects the Peruvian Amazon. *Science,* 317: 1233–1236.

Russia

Cushman, S. A., and D. O. Wallin (2000) Rates and patterns of landscape change in the Central Sikhote-alin Mountains, Russian Far East. *Landscape Ecology,* 15**:** 643-659.

Spain

Alodos, C., Y. Pueyo, O. Barrantes, J. Escós, L. Giner, and A. Robles. (2004) Variations in landscape patterns and vegetation cover between 1957 and 1994 in a semiarid Mediterranean ecosystem. *Landscape Ecology,* 19**:** 543-559.

Tanzania

Pelkey, N. W., C. J. Stoner, and T. M. Caro. (2000) Vegetation in Tanzania: assessing long term trends and effects of protection using satellite imagery. *Biological Conservation,* 94**:** 297-309.

Tabor, K., N. D. Burgess, B. P. Mbilinyi, J. J. Kashaigili, and M. K. Steininger. (2010) Forest and woodland cover and change in coastal Tanzania and Kenya, 1990 to 2000. *Journal of East African Natural History,* 99**:** 19-45.

Thailand

Cropper M, Puri J, Griffiths C. (2001) Predicting the Location of Deforestation: The Role of Roads and Protected Areas in North Thailand. *Land Economics*, 77: 172–186.

Uganda

Mulley, B. G., and J. D. Unruh. (2004) The role of off-farm employment in tropical forest conservation: labor, migration, and smallholder attitudes toward land in western Uganda. *Journal of Environmental Management,* 71**:** 193-205. DOI:

United States

Luque, S. S. (2000) Evaluating temporal changes using Multi-Spectral Scanner and Thematic Mapper data on the landscape of a natural reserve: the New Jersey Pine Barrens, a case study. *International journal of Remote Sensing,* 21**:** 2589-2610.

Zimbabwe

Mapaure, I. N., and B. M. Campbell. (2002) Changes in miombo woodlan cover in an around Sengwa Wildlife Research Area, Zimbabwe, in relation to elephants and fire. *African Journal of Ecology,* 40**:** 212.

Global Studies

Bruner AG, Gullison RE, Rice RE, da Fonseca GAB. (2001) Effectiveness of Parks in Protecting Tropical Biodiversity. *Science*, 291: 125–128.

DeFries R, Hansen A, Newton AC, Hansen MC. (2005) Increasing isolation of protected areas in tropical forests over the past twenty years. *Ecological Applications,* 15: 19–26.

Joppa LN, Pfaff A. (2010) Global protected area impacts. *Proceedings of the Royal Society B*: *Biological Sciences*, 278(1712): 1633-1638.

"BirdLife International, Conservation International, and Wildlife Conservation Society - Myanmar Program (2013) Key Biodiversity Areas of Myanmar. BirdLife International, Cambridge, UK, Conservation International and Wildlife Conservation Society - Myanmar Program, Arlington, VA USA. These data represent a subset of global Important Bird Areas developed and maintained by the BirdLife partnership and Key Biodiversity Areas developed and maintained by Conservation international and partners. Please contact science@birdlife.org or data@conservation.org for further information."

Appendix: WDPA Variables Used for Regression Analysis

1. Establishment year: the year in which the current status was officially decreed.

2. Park Status

Designated: recognized or dedicated through legal or other effective means. Implies a specific binding commitment to conservation in the long term.

Inscribed: Inscribed as a UNESCO World Heritage Site.

Proposed: in a process to gain recognition or dedication through legal or other effective means.

3. IUCN Status

Ia: Strict Nature Reserve: strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values.

Ib: Wilderness Area: usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

II: National Park: large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.

III: Natural Monument: areas set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.

IV: Habitat Management Area: areas that aim to protect particular species or habitats, with management reflecting this priority. Many of these areas need regular, active interventions to address the requirements of particular species or to maintain habitats.

V: Protected Landscape: areas where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

VI: Sustainable Resource Use: areas that conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area

4. Protected Area Management Category

Management by Government

- National ministry
- Sub-national ministry
- Delegated by government

Shared Management

- Collaborative management
- Joint management

Private Management

- Private governance, not otherwise specified
- Individual landowners
- Non-profit organizations
- For-profit organizations

Local management

- Indigenous peoples
- Local communities