Buffer zones in the Peruvian Amazon bring conservation benefits despite ambiguous rules and uncertain authority

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Abstract

Many geographers have tested whether protected areas save forest, but they usually focus on parks and reserves, management units that have internationally recognized standing and familiar objectives. Buffer zones have received considerably less attention because of their ambiguous rules and often informal designation. Although buffer zones are often dismissed as an ineffective conservation tool, their prevalence in the Amazon and especially in Peru (where they cover over 10% of the country) calls for increased attention. This study examines the effectiveness of buffer zones in the Peruvian Amazon to: a) prevent deforestation and b) limit the extent of extractive concessions (a primary goal of buffer zone legislation). I employ annual deforestation data from the Hansen et al (2013) Global Forest Change dataset with covariate matching to determine the impact of 13 buffer zones on deforestation from 2007-2012. I find that despite uncertainty in management authority, buffer zones are associated with fewer extractive concessions and less deforestation. To understand causality of the result I draw on interviews with government officials and NGO employees in Lima and around the Tambopata National Reserve, the site of my case study. The approval process for extractive concessions in buffer zones appear to slow legal extractive activities, but management of illegal activities is ambiguous and less effective. In the Tambopata National Reserve, buffer zone managers have been unable to control the boom of illegal gold mining within the buffer zone. These results call for increased clarity in management rules and more research into the potential role of buffer zones as a conservation strategy.
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1. Introduction

Protected areas (PAs) are a key conservation strategy for preserving biodiversity, maintaining vital ecosystem processes, and sustaining cultural values and livelihoods (Possingham et al., 2006). However, current PAs alone are not sufficient in achieving these goals (Margules and Pressey, 2000). In addition, PAs are becoming increasingly isolated on the landscape, as habitat loss continues around PA borders (DeFries et al., 2005). This isolation is of major concern for PAs: in fact, research suggests that environmental changes immediately outside of PAs are nearly as important as changes within PAs in determining ecological health (Laurance et al., 2012). Thus, conservationists are increasingly investing in landscape-level conservation initiatives, which often have fewer restrictions on resource use than PAs and attempt to incorporate local people into conservation efforts.

Buffer zones in Peru are an example of this strategy, as they are designed to protect PAs from outside threats while still allowing some human activity. Balancing conservation and development is a lofty, complex goal (see Naughton-Treves et al., 2005), yet buffer zones and other landscape-level conservation efforts often have little economic or political support. Nonetheless, they represent an opportunity for improving ecosystem connectivity and local livelihoods. This study will provide insight into these landscape-level initiatives by examining the impacts of buffer zones in Peru, identifying problems, and suggesting potential solutions.

I aim to quantify the impact of 13 buffer zones in the Peruvian Amazon on deforestation and mining concessions. Deforestation is a familiar estimate of effectiveness, used in many studies of PA effectiveness (e.g. DeFries et al., 2005; Nepstad et al., 2006).
Estimating buffer zones’ impact on the issuance of mining concessions is a novel approach but a potentially urgent one given the spread of mining activities in remote tropical areas (Durán et al, 2013; Alvarez-Berríos & Aide, 2014). In this case, reducing mining concessions was in fact a key goal of buffer zone legislation. In addition to quantitative analyses, I use information from interviews to help explain the observed patterns and recommend improvements to the system. I also use a case study in the Tambopata National Reserve buffer zone to show an example of buffer zone response to widespread illegal activity.

In Chapter 2, I review the relevant literature. First, I explore the concept of buffer zones and other studies that have discussed the effectiveness of buffer zones. I then delve into buffer zone legislation in Peru. Next, I delve into what it means for a buffer zone to be effective. Here, I outline my decision to use both forest loss and the spread of concessions as measures of effectiveness. Finally, I explain statistical matching, a technique I use to control for potentially important covariates, and trace its use through the PA effectiveness literature.

In Chapter 3, I present the analysis of buffer zone effectiveness at a national level. I outline my methodology for performing matching on deforestation and mining concessions for the 13 studied buffer zones and for conducting interviews in Lima and Puerto Maldonado. Then, I present the results of the quantitative analyses. I next draw upon interviews to understand the impact of buffer zones on development, the largest issues in management, and the ways that management can be improved. I conclude by placing the results in the context of other studies and the wider literature on conservation.

In Chapter 4, I move to my case study in the buffer zone of the Tambopata National Reserve in southeastern Peru. I explain my interest in the Tambopata buffer zone as an area that is under threat from a boom in illegal mining. Then I delve into my methodology for
determining the impact on deforestation and concessions, and for interviews. I present my results, and draw on the interviews to help explain them. In particular, I examine the lack of follow-through with agency responsibilities, problems with the government response to the mining boom, the involvement of community groups in the buffer zone, and pathways for improvement.

In Chapter 5, I conclude the thesis with final thoughts on the Tambopata case study and the national analysis, as well as calls for further attention to buffer zone management globally.

In Chapter 6, I present a summary in Spanish highlighting the main findings of the study in an abbreviated form targeting policy makers.

It is my hope that this thesis will assist those working to improve buffer zone management in Tambopata and Peru as a whole, will ignite interest in using concessions as an indicator of effectiveness, and encourage more deliberate attention to why certain categories of land use are granted instead of simply looking at the outcomes of those decisions. Most broadly I hope to encourage conservationists around the world to reconsider buffer zones as an important tool in landscape-level conservation.
2. Literature Review

2.1 Buffer zones as a conservation strategy

2.1.1 Buffer zones around the world

Buffer zones gained widespread popularity with the creation of UNESCO’s Man and the Biosphere program in 1979, which created reserves made up of a core protected zone surrounded by a buffer (Wells et al., 1992). Buffer zones are now a key part of Biosphere Reserves and are widespread around other PAs. These zones are often managed for the dual goals of conservation and development (Sayer, 1991). On the conservation end, buffer zones are intended to shield the “core” protected area from harmful outside threats, make the boundary of protected areas more gradual, and increase the connectivity of the landscape (Bennett and Mulongoy, 2006). Socially, buffers are meant to resolve conflicts between conservation interests and local communities, compensate people for loss of access to the PA, and improve the earning potential of local people (Sayer, 1991). However, buffer zones have had mixed results delivering on both development and conservation goals.

Several studies have pointed to local economic benefits from buffer zone implementation (e.g. Lynagh & Urich, 2011), but others have criticized buffer zones as a form of top-down control by the state or by local authorities (e.g., Neumann, 1997; Heinen & Mehta, 2000; Budhadthoki, 2004). Neumann (1997) described the implementation of buffer zones in sub-Saharan Africa as “a geographical expansion of state authority beyond the boundaries of protected areas and into rural communities” (p.564, emphasis in original).

With regard to environmental goals, some studies have shown a modest impact of buffer zones on deforestation and degradation (e.g. Nagendra et al, 2004; Scullion et al,
2014), but many more have deemed buffers ineffectual in protecting forests (e.g., Gilmour & Van San, 1999; Heinen & Mehta, 2000; Schelhas & Sanchez-Azofeifa, 2006; Lynagh & Urich, 2011; Mehring & Stoll-Kleeman, 2011). Some blame poor conservation outcomes in BZs on a disproportionate management emphasis on socioeconomic interests versus ecological goals, such as in the cases of Thailand (Gilmour & Van San, 1999) and Nepal (Heinen & Mehta, 2000). Others blame low local awareness of the buffer zone and its boundary, often due to the limited local participation in buffer zone demarcation (e.g., Mehring & Stoll-Kleeman, 2011). Another important obstacle to successful buffer zone implementation is the ambiguity of who is in charge of management and what activities should be allowed within the zone (Wells et al, 1992; Mehring & Stoll-Kleeman, 2011). This is a pervasive problem for within-PA zoning as well; in some cases the uncertainty itself hastens deforestation (Naughton-Treves, 2012). PA managers often do not have the authority to create buffer zones, since the buffer land is often located outside of the park (Wells et al, 1992). Others have solved this problem by designating the buffer within the PA boundary, effectively shrinking the strictly protected zone (e.g. the intentional deforestation of the Kenyan Kakamega Forest edge to create a buffer of tea plantations; Wambui Kariuki, 2008). Mehring & Stoll-Kleeman (2011) point to buffer zone failure in the Lore Lindu forest reserve in Indonesia due to uncertainty over who is legally responsible for sustainably managing forest in the buffer and ensuring local participation. The rules of use within buffer zones may also be quite weak, such as in the case of Costa Rica, where buffer zone land does not have any additional restrictions on use and thus does not create any additionality (Schelhas & Sanchez-Azofeifa, 2006).
2.1.2 Buffer zone policy and management in Peru

In Peru, buffer zones are defined as areas adjacent to PAs that “because of their nature and location, require special treatment to guarantee the conservation of the PA” (Law No. 26834, Article 25). According to the law, “the activities realized in the Buffer Zones should not put the objectives of the Natural Protected Area at risk”. A key intent of buffer zone establishment was to control the rapid expansion of mining, oil, and natural gas extraction around Peru’s protected areas (G. Suarez de Freitas, INEFAN, pers. comm. 2002), as these are major wide-spread threats to tropical forests on the Peruvian frontier (e.g., Asner et al., 2013; Finer et al., 2008). Buffer zones were first created in 1997, with the passage of a new Peruvian National Protected Areas Law. The rules of buffer zone use were then further outlined in Supreme Degree 038-2001-AG, and the first national buffer zone was designated in 2001. Buffer zones are designated around each PA within its Plan Maestro (Law No. 26834, Article 25), the highest-level planning document for the PA, modified via a participatory process and approved by the National Government every 5 years (Law No. 26834, Article 20).

Buffer zone management, along with national PA management, is handled by the national agency SERNANP (National Service of Natural Protected Areas). SERNANP’s main role within buffer zone management is to emit a binding opinion “before the granting of rights for the use of natural resources and/or the modification of infrastructure” (Supreme Decree Nº 038-2001-AG, Article 116) within the buffer zone. The binding opinion of SERNANP has two stages: compatibility and Favorable Technical Previous Opinion (OTPF in Spanish) (Figure 1). The compatibility stage deals with proposed concessions within the buffer zone. The potential concessioner applies for a concession from the relevant
government agency (e.g. the Ministry of Energy and Mines for mining concessions), who then brings the request to SERNANP for approval. Officials in SERNANP then decide whether or not to allow the concession based on the “category, zoning, Plan Maestro, and objectives of the area in question” (Supreme Decree Nº 038-2001-AG, Article 116). After SERNANP emits a favorable compatibility decision, the relevant agency may grant the concession. However, they cannot extract until they present their Instrument of Environmental Management for approval.

The OTPF stage begins when the concessioner decides to begin extractive activities in their concession. The concessioner must present their Instrument of Environmental Management (such as an Environmental Impact Statement) to SERNANP, who may approve or deny it, or impose conditions for approval. These conditions may include increased study on the potential impact of the activity to the park, improved monitoring plans, or altered equipment usage. In this way, SERNANP can mitigate the negative impacts of the extractive activity without completely disallowing it. The Instrument of Environmental Management “can only be approved by the competent agency if it has a Favorable Technical Previous Opinion from SERNANP” (Supreme Decree Nº 038-2001-AG, Article 116). SERNANP does not have responsibility for enforcement in the buffer zone, although it the law states that “a copy of the reports of supervision and control by competent authorities should be submitted to SERNANP” (Supreme Decree Nº 038-2001-AG, Article 116).

In addition to determining which activities are allowed in the buffer zone, SERNANP is also supposed to promote sustainable resource use such as ecotourism, conservation concessions, agroforestry, and research within the buffer zones (Supreme Decree No. 038-2001-AG, Article 62.1). Each park’s Plan Maestro is supposed to establish criteria for
promoting these activities, prioritizing proposals involving local communities. This is the only mention of local people in the legislation, suggesting that, unlike buffers in Nepal and other countries, Peruvian buffer zones are not striving to preserve traditional livelihoods or compensate people for the loss of reserve resources. As opposed to buffers elsewhere that emphasize dual goals of conservation and development, Peruvian buffer zones focus on environmental outcomes for the PA as a primary goal.

By 2013, 57 buffer zones had been implemented around nearly all Peruvian PAs, totaling 145,917 km², or about 11% of Peru’s land surface (national PAs comprise an additional 15%). The amount of land designated as buffer zone in Peru is about 2.8 times the size of the entire nation of Costa Rica. As they encompass such a large area, it is inappropriate to simply dismiss these buffers as an ineffectual strategy. Rather, they should be examined systematically to determine the extent of their impact and to suggest improvements to their implementation.

2.2 Buffer zone effectiveness

2.2.1 What makes a buffer zone effective?

One major challenge in determining effectiveness is deciding how to define an effective buffer zone. As discussed above, buffer zones are often expected to improve both environmental (forest cover, biodiversity, connectivity, etc.) and social (employment, resource access, etc.) outcomes. Ideally, all of these factors would be considered in evaluation, but practically, this would be difficult, especially given the vast size and low data availability of Peru’s buffer zones. Additionally, since buffer zones are meant to promote
conservation within the PA, an ideal situation would be to measure the impact of the buffer zone on the PA itself. However, it is difficult to prove causal impacts with such a small sample size and short time frame. Instead, this study focuses on environmental outcomes within the buffer zones themselves, particularly those of greatest concern to conservationists: forest loss and the spread of extractive concessions. Forest loss is the most common way of assessing tropical forest effectiveness, while assessing buffer zone impact on mining concessions is a novel approach that can more accurately test whether the legislation is functioning. Conservation researchers have already determined that deforestation is worse in concessions superimposed on buffer zones (Scullion et al., 2014), but it is equally important to determine whether conservation policies can slow the issuance of concessions in the first place. Not only do these factors demonstrate the impact in the buffer zone itself, they also have major implications for the PA, as deforestation and mining near PAs are shown to have detrimental impacts on the PAs themselves (Laurance et al, 2012; Duran et al, 2013). Additionally, deforestation rates and mining concessions within PAs are so minimal that it would be difficult to detect significant changes to assess effectiveness. The two factors of effectiveness used in this study are described more thoroughly below.

2.2.2 Forest loss as a measure of effectiveness

One of the most common factors used in PA effectiveness studies is land-cover change from remotely sensed data. Remote sensing has become a major tool for measuring effectiveness because it can capture high-resolution data over a broad area. Along with automation and powerful GIS tools, it greatly reduces the cost of analyzing landscape-level phenomena compared to field studies (Blackman, 2013). In addition, repeat coverage and
historical archives of remote sensing imagery allow researchers to analyze land cover change with greater temporal depth (Turner, 2003). Land cover change is often used as a proxy for other indicators of ecological effectiveness because in tropical forests, deforestation often signals a decline in available habitat, an increase in human pressure on the area, and a reduction of connectivity. Land-cover change as an indicator of effectiveness is certainly not perfect. For example, the most commonly used data (i.e. from Landsat and MODIS) are too coarse of a resolution to assess forest degradation, which in the Brazilian Amazon, affects as much land as deforestation with important implications for carbon storage (Asner et al, 2005). In another example, hunting is one of the most prevalent human land uses in tropical forests (e.g. Naughton-Treves et al, 2006) and can result in altered species composition, decreased seed dispersal, and local extinctions, even though forest cover may remain intact (Redford, 1992; Peres, 2000). Although forest loss does not adequately assess all factors of effectiveness, Barber et al (2012) points out, “assessments of factors such as hunting pressure, biodiversity maintenance, or vulnerability to wildfire become secondary if forest cover is not preserved when considering forest dependent species” (p. 8). Forest cover serves as a rough indicator of effectiveness, as many other conservation objectives, such as maintenance of ecosystem services and biodiversity, depend on the presence of forest.

Forest cover loss is relatively easy to determine in heavily forested regions like the Amazon because the forest canopy has a spectral signature that is distinct from bare ground. PA effectiveness studies tend to measure the deforestation rate based on one start date and end date and examine a dichotomous variable of whether each pixel was cleared during the study period (Blackman, 2013). Few studies use a study period of over 20 years: Naughton-Treves et al (2005) find an average study period of 13 years for the 20 studies they compiled.
on park effectiveness measures using remote sensing in tropical forests. The selection of image resolution varies depending on the scale of the study area, with Landsat (30m resolution) used primarily for medium-scale areas and MODIS (250m to 1km resolution) used for wide-scale analyses (Naughton-Treves et al, 2005).

The biggest challenge of assessing effectiveness using deforestation rates is that it is impossible to measure the counterfactual – or what would have happened in a location without the presence of a park (Blackman, 2013). Since the counterfactual can never be observed, analysts must use other means to estimate what the deforestation rate would have been in the absence of the park. The most common method has been to compare the rate of forest loss within the PA to the rate of forest loss just outside its borders (e.g., DeFries et al, 2005; Nepstad et al, 2006). However, this method does not take into account the problem of non-random siting. PA location is not random on the landscape: instead PAs are biased towards areas with high elevation, steep slopes, and large distances to roads and markets (Joppa and Pfaff, 2009), which are less likely to experience land conversion. Thus the observed difference in deforestation rates between protected and unprotected areas may be due to this bias of location rather than the effect of protection (Blackman, 2013). For example, the rate of forest loss just outside a PA or buffer could be higher because that area is closer to a road that allows access to the forest by loggers and agriculturalists. In this case, the measurement of effectiveness would be confounded by differentiated access in the outside area versus in the PA or buffer zone.

One increasingly popular way to address these problems is to use matching methods to control for potential biases in location. Beginning with a seminal paper in 2008 by Andam et al, matching is now the preferred method of estimating the counterfactual in PA
effectiveness studies (Blackman, 2013). Matching pairs protected locations to unprotected locations with similar landscape characteristics, allowing for an “apples to apples” comparison (Joppa & Pfaff, 2010). By comparing areas that are similar distances to cities, roads, and rivers, some of these confounding variables can be controlled. Matching techniques draw criticism from some analysts due to the underlying assumption that all confounding variables are visible and included in the study (Caliendo & Kopeinig, 2005). While this is difficult to test, this study controls for variables that have proven to be powerful predictors of deforestation elsewhere in the Amazon (e.g. roads, rivers, urban centers). Statistical matching and examples of its use in PA effectiveness studies are explored more fully in section 2.3.

2.2.3 Lack of concessions as a measure of effectiveness

While forest loss is a common measure of effectiveness and remotely sensed data is easily accessible, land cover change represents only one aspect of effectiveness, and the prevention of deforestation was not a direct goal of the buffer zone legislation in Peru. Rather, the legislation aims to “guarantee the conservation of the PA” (Law No. 26834, Article 25). This goal is somewhat lofty and ambiguous, but the tool SERNANP uses to carry out this goal is to approve or deny the use of resources within buffer zones. Thus to test buffer zone effectiveness, this study also examines the impact of buffer zones on the spread of extractive concessions, which are almost always incompatible with PA goals. In addition to representing a direct threat to PA biodiversity, these concessions should be directly reduced by buffer zone management. Thus an effective buffer zone would exclude most new
mining and petroleum concessions, as they are rarely in line with PA and buffer zone objectives and may impact the ecological integrity of the PA.

As Peru adopted neoliberal development policies, conditions improved for foreign investment in extraction; indeed, foreign direct investment in Peru reached $20.8 billion in 2010, with $4.8 billion in mining and $2.8 billion in energy and hydrocarbon (Gurmendi, 2012). Oil and gas concessions expanded from 7.1% of the Peruvian Amazon in 2003, to 48.6% in 2009, which could lead to a second hydrocarbon boom in the region with major environmental impacts (Finer & Orta-Martinez, 2010). Oil and gas expansion harm ecosystems directly through infrastructure expansion and petroleum contamination, and often improve access to previously remote areas which may cause deforestation (O’Rourke & Connelly, 2003; Orta-Martinez et al, 2007; Baynard et al, 2013). Mining also causes adverse ecological impacts, such as mercury contamination, which can be detected tens of kilometers downstream from the mining source (Duran et al, 2013). Alluvial gold mining in southeastern Peru is a major driver of deforestation (Swenson et al, 2011) and a source of mercury contamination in water, fish, and even human bodies (Ashe, 2012).

Despite the apparent incompatibility of extraction and nature conservation, the national government has promoted both activities in Peru. Bury & Norris (2013) reflect on these contradictory interests in their political ecology of the subsoil in the Cordillera Huayhuash:

Mining and nature-based tourism – which is predicated on the conservation of nature and historical monuments – have, respectively, become the largest and second-largest sectors of Peru’s economy. … both have become the frontiers of environmental and social change expanding across the country’s diverse landscapes and are the fault lines around which resistance and struggles are emerging (p. 99)
Government promotion of these two very different forms of natural governance has led to conflict, such as protests and violence over the Yanacocha gold mine in Cajamarca (“Tangled Threads”, 2010). In Peru, there are also concerns of oil & gas blocks overlapping less strictly protected areas like Communal Reserves, although blocks are not allowed to overlap with national parks and sanctuaries (Finer et al, 2008). In other areas of the Amazon, such as Ecuador and Bolivia, hydrocarbon concessions are allowed even within national parks (Finer et al, 2008). There are also cases of mining concessions overlapping with PAs in Ecuador, most notably in Podocarpus National Park where official concession maps did not even note the existence of the PA (Tello et al, 1998).

Buffer zone legislation emerged in large part as an attempt to lessen the threats of extractive activities around PAs in Peru. The legislation attempts to reduce new extractive concessions within buffer zones, a goal that has not been reached even inside of PAs in other parts of the Amazon (Finer et al, 2008). Therefore, the presence of new mining and petroleum activities can serve as another indicator of effectiveness. If there are fewer concessions granted in buffer zones than expected, then this suggests that the buffer zone is effective. Deforestation analyses may be the norm for measuring the effectiveness of strictly protected areas, but they are inadequate to assess buffer zones, where the primary goal is not to reduce deforestation. Thus I will assess buffer zone effectiveness in excluding extractive concessions as well as slowing deforestation. As with the deforestation analysis, I use covariate matching to reduce the impact of locational bias inherent in buffer zones and in extractive concessions. Beyond informing Peruvian conservation efforts, this study will provide an example of a novel measure of effectiveness.
2.3 Statistical matching

2.3.1 Matching basics

Matching is a statistical technique used to reduce bias in data by pairing observations with similar characteristics. It is considered “quasi-experimental” because it aims to mimic the random distribution of treatment (Ho et al, 2006). Observations are paired based on their similarity in regards to confounding variables, so that the only difference determining the dependent variable, in theory, is the treatment. In the PA effectiveness literature, the treatment is protection status. The observations are normally individual pixels or cells, and the dependent variable is the rate or presence of deforestation. The researcher controls for observed confounding variables, such as proximity to roads, elevation, etc. (to be more fully discussed in the next section) to control for the biased location of PAs in remote, high-elevation areas.

The two main methods of statistical matching are covariate matching (Rubin, 1980) and propensity score matching (Rosenbaum & Rubin, 1983). The covariate method matches each treated observation to the closest untreated observation, as determined via the Mahalanobis distance, which is a scale-invariant measure for n-dimensions of covariates (Sekhon, 2011). The analyst can potentially choose to use only exact matches for covariates, but this is unrealistic with continuous data and multiple covariates. It is also possible to require exact matches on certain covariates and minimize the distance of the other covariates. Propensity score matching, on the other hand, is based on the probability (often calculated with a logistic regression) that a given observation will be treated, given its covariates. Treated observations are then matched to untreated observations with the closest probability, or propensity score (Caliendo & Kopeinig, 2005). Of the two, there is not one that emerges
as the best matching estimator (Zhao, 2004). Genetic matching has emerged as a new matching method (Diamond & Sekhon, 2006). This method is similar to covariate matching in that it uses the distance based on all covariates, but genetic matching uses an evolutionary search algorithm to determine the best weight given to each covariate. This method improves the amount of bias that can be removed, but at the expense of computational time. Propensity score matching, covariate matching, and genetic matching can all be implemented in Sekhon’s (2011) matching package for R.

The analyst must also decide whether to match one-to-one, i.e. one untreated observation for each treated observation, or to match multiple untreated observations to each treated observation and take a weighted average of the outcome (Caliendo & Kopeinig, 2005). Another decision is whether to match with replacement, which allows multiple treated observations to be matched to the same untreated observation. Replacement will allow for better, less biased matches, but may result in the use of a very small sample of untreated observations (Zhao, 2004). Finally, another common method is to use a caliper, or a maximum distance tolerance, to prevent bad matches (Caliendo & Kopeinig, 2005).

Once the observations have been matched, the analyst must do some sort of test to determine the effect of the treatment after biases have been removed. Commonly in the PA effectiveness literature, this post-matching test is a simple difference-in-means test to determine if the “average treatment effect on the treated” (ATT) (Blackman, 2013). However, Ho et al (2006) argue that except in the rare cases when exact matching is possible, this is inappropriate since there are still some biases that remain in the data. They suggest that analysts use another parametric test (such as a regression) to account for these differences. Instead of thinking about “matching”, they argue that these methods should be
called “pruning” to signal that this is a pre-processing step to make the two groups to be compared more similar to one another.

Matching removes much of the selection bias inherent in many protected area effectiveness studies that may confound results (e.g., remoteness, elevation), but it still has two major assumptions that do not always hold. The first is conditional independence, or the assumption that all confounding variables are observable and have been included in the analysis. Of course, this may not always be the case if important factors are unmeasured (for example, deforestation may be directly related to enforcement effort, which is very difficult to measure). Second is the stable unit treatment value assumption, where untreated units are not affected by treatment elsewhere, known better in the PA literature as leakage (Blackman, 2013). This assumption may not hold if the protection in one area either slows deforestation in the untreated landscape (e.g. if a park prevents road expansion in the area that would bring deforestation to the unprotected areas around it) or increases it (e.g. if people living inside the park are displaced to areas around it, and subsequently increase the deforestation rate). While these two assumptions do not always hold in studies of PA effectiveness, matching still provides a more robust method for estimating the counterfactual than the traditional technique of comparing PAs to outside areas without controlling for confounding variables. The next section explores how statistical matching has been used to determine PA effectiveness in Latin America.

2.3.2 Examples of matching studies for PA effectiveness in Latin America

Among the first studies to assess PA effectiveness using matching is Andam et al (2008), which compared estimates of avoided deforestation in Costa Rica using conventional
approaches and matching approaches. They found that conventional approaches, such as before and after comparisons or comparison to nearby areas, overestimated the amount of avoided deforestation by more than 65%. The authors called for more rigorous empirical assessment to evaluate conservation outcomes and many other researchers have since adopted this approach. Pfaff et al (2009) likewise studied Costa Rica, and found that PAs located in areas of higher pressure avoided more deforestation. They call for more PAs located in these priority areas in order to maximize their impact.

Joppa & Pfaff (2011) applied matching on a global scale, and found that PAs avoid land cover change, but by less than previously estimated. Nelson & Chomitz (2011) applied matching in the tropics, and found that Latin American indigenous reserves were actually more effective than estimated by conventional methods and avoided more deforestation than strictly protected areas, since indigenous reserves are generally located in areas of much higher deforestation pressure.

Matching analyses found similar results at regional and local scales. In the Brazilian Amazon, Nolte et al (2013) found that indigenous lands were the most effective type of protection under high deforestation pressure. Pfaff et al (2014) focused on the state of Acre in the Brazilian Amazon and found that sustainable use areas are better at avoiding deforestation because they are in areas of higher threat. Unlike Nolte et al (2013) and Nelson & Chomitz (2011), they conclude not that sustainable use areas are more effective, but that all PAs should be more preferentially located in areas of high pressure to have the maximum impact possible. Scullion et al (2014) worked in Madre de Dios, Peru (the case study in this thesis) and found that conservation areas generally slow ecosystem conversion, but not where concessions were inscribed in protected areas. In the Maya Biosphere Reserve in Guatemala,
Blackman (2014) determined that contrary to prior studies which assumed that mixed use areas were working better, the mixed use areas were about as effective as strictly protected areas. Taken together, these eight studies reveal that matching provides a more robust form of measuring effectiveness than conventional techniques which are likely to overestimate the amount of avoided deforestation. Many of the studies also found that mixed use areas and indigenous reserves resulted in more avoided deforestation than strictly protected areas, because strict PAs tend to be located in isolated areas (often due to public resistance to strict protection in populated areas and the higher cost of land).

Table 1 demonstrates the covariates that were used in the eight examples from Latin America. The most important are the distance to roads and distance (and travel time) to cities, both of which are crucial to understanding an area’s accessibility. In forest frontier regions, distance to roads is a strong predictor of deforestation as people settle and perform extractive activities in the most accessible areas (Geist & Lambin, 2002; Pfaff et al, 2007), and distance to cities gives insight into areas that likely have more economic opportunities due to off-farm income and market accessibility (Lambin & Meyfroidt, 2008). Other important variables that are commonly used in PA matching studies include distance to the forest edge (also related to remoteness), elevation, slope, agricultural suitability, and rainfall.

Most of the studies used a nearest neighbor approach using all of the covariates to determine matches, but some also incorporated exact matching. For example, Nelson & Chomitz (2011) matched parcels exactly on travel time to cities in 15 minute increments and in country, as they determined these to be the most important covariates. They then used the nearest neighbor approach to match the remaining confounding variables. Unlike regressions, where the significance of each variable is determined, matching does not have a mechanism for
Determining the importance of the covariates. Andam et al (2008) tried to incorporate other covariates into the study to test their importance. They found that the second group of covariates (distance to railroads and rivers, population density, number of immigrants, education level, poverty, size of administrative district) did not have an impact on the results, so they reported results only on their original covariates (land use productivity, distance to the forest edge, distance to roads, distance to a major city).

Table 2 shows the matching technique used in each of the eight studies reviewed for this paper. Matching methods varied: four studies used covariate matching, two used propensity score matching, and one used genetic matching. All of the studies that reported the software used Sekhon’s (2011) matching package for R, which is capable of performing all three methods of matching. The studies that tried matching both with calipers and without calipers did not report which method produced better results. Generally, results from both techniques were reported to increase robustness. Using a caliper improves the quality of matching, but results in unmatched observations that can bias the results. Other studies used multiple nearest neighbors to create the control sample rather than a single match per treated observation. Of the eight studies, seven used a difference-in-means or average treatment effect on the treated approach to evaluate the effect of treatment after matching. The exception was Nolte et al (2013), which applied a regression on the matched data, as promoted by Ho et al (2006).

This study draws upon the techniques used in these examples to determine the effectiveness of buffer zones in the Peruvian Amazon at reducing deforestation. In addition, I expand these techniques to also apply to mining concessions as another method of assessing effectiveness. My methodology is detailed in the next section.
3. National Analysis

3.1 Methods

This study assesses the effectiveness of 13 buffer zones surrounding 17 PAs (Table 3, Figure 2) in the Peruvian Amazon. These buffers were selected using the following criteria:

- The PA that the buffer surrounds is managed by the National Service of Natural Protected Areas (SERNANP).
- Over 70% of the PA and its buffer are part of the Tropical and Subtropical Moist Broadleaf Forest biome as defined by the WWF Terrestrial Ecosystems of the World (Olson, 2001).
- The buffer zone was legally established in or before 2007.
- The PA has an area of at least 100 km², which is generally considered the minimum area to conserve larger species important for forest health (Terborgh, 1992; Michalski & Peres, 2007).

Sunchubamba National Park met these criteria but was dropped from the study because the buffer zone contained too little forest to perform the analysis. Shapefiles for PAs and their buffers come from SERNANP (see Table 4 for shapefile source information).

3.1.1 Deforestation analysis

The first way I test the effectiveness of these buffers is to determine their impact on deforestation. I utilize the Global Forest Change data created by Hansen et al. (2013) that provides global coverage of forest change derived from Landsat imagery at 30m resolution for 2000-2012. Specifically, I use the year of forest loss for the 10 by 10 degree granules.
starting at 0°N 80°W, 10°S 80°W, and 10°S 70°W. Hansen’s team determined the producer’s and user’s accuracies to be 83.1% and 87%, respectively, for forest loss in the tropics. They also report that the year of loss matched for 75.2% of the checked blocks, and fell within a year before or after for 96.7% of them. While reforestation is also an important land use change, it is beyond the scope of this study. Some critics of the Hansen dataset argue that the algorithm commonly confuses plantations with forest cover (Tropek et al, 2014), but plantation crops are relatively minor in Peru; they cover only 1.5% of forested land (FAO, 2010). The dataset also cannot detect selective-logging or other forms of forest degradation, and thus is an underestimate of total forest loss. Despite these limitations, the Hansen data set is widely used in conservation effectiveness research and is an adequate data source to determine broad differences in deforestation in Peru’s buffer zones compared to unprotected areas.

First, I simply compare rates of deforestation within the buffer and in the surrounding area, defined as the area within 10 km of the outer boundary, excluding areas that overlap with other PAs or buffer zones. Deforestation rates are determined by dividing the number of pixels deforested during each year by the total number of pixels that were forested in 2007. These rates are calculated for 2007 to 2012, since all of the selected parks had established buffer zones by this time. I calculate avoided deforestation by subtracting the rate of deforestation in the buffer zone from the rate in the surrounding area.

Although comparing the yearly rates of deforestation in buffer zones and neighboring areas does provide a rough estimate of effectiveness, it does not account for biases in PA and buffer location and characteristics (Joppa & Pfaff, 2010). Thus I also implement covariate matching to account for these confounding variables, which include distance to roads,
distance to population centers (population > 50,000), distance to the forest edge, distance to rivers, suitability for agriculture, slope, elevation, and department (administrative unit). The distances to roads, cities, and the forest edge are among the most commonly used covariates in PA effectiveness studies (see section 2.3.2), as accessibility is a major factor in deforestation risk on the forest frontier. I also included distance to rivers as a covariate because it also relates to accessibility and because alluvial mining is a major source of deforestation in Peru, especially in the region of Madre de Dios. Slope, elevation, and agricultural suitability are other common covariates that relate to the risk of conversion to agriculture or activities like mining that drive deforestation. Including department controls for variation that may occur in the policies or drivers of deforestation in different regions.

Matching methods assume that all relevant covariates are included in the analysis. While there is no way to verify this assumption, I follow the lead of other studies of PA effectiveness (see Table 2). Table 4 shows the data sources and years for all shapefiles. All distances were computed in ArcGIS 10.1 with the “Near” tool.

To reduce data volume and spatial autocorrelation, I selected the sample for matching by overlaying a 1km by 1km grid on Peru in ArcGIS and using the corners as sample points (a similar technique is used by Blackman, 2014). Then points that had less than 50% forest cover in 2000 or that were deforested from 2001 to 2007 (from the Hansen data) were removed from the sample. Points that fell inside of national PAs, regional PAs, or other buffer zones were also removed. The remaining points were then populated with the distance to cities with a population greater than 50,000 (all distances in km), distance to paved or finished roads, distance to the nearest non-forest observation, distance to rivers, agricultural suitability (scale from 0 to 9), elevation (in m), slope (in degrees), a dummy variable for
department, a dummy variable for whether the point fell inside a target buffer zone, and a
dummy variable for whether the point had been deforested from 2007 to 2012. The resulting
attribute table was exported as a csv file to use in R 3.1.0.

I use the matching package in R (Sekhon, 2011) to perform covariate matching. The
dummy variable for buffer zone serves as the treatment variable, deforestation as the
outcome, and the other variables as covariates. Pixels are matched on a one-to-one basis
without replacement using the nearest neighbor based on Mahalanobis distance (Rubin,
1980), with the exception of department, which is matched exactly. I did not use a caliper, as
many studies of this type have found similar results with and without the use of a caliper.
From the matched data, I estimate the “average treatment effect on the treated” (ATT), or the
impact of buffer zone designation on deforestation for treated pixels. I also calculate the area
of avoided deforestation by multiplying the ATT (a percentage) by the buffer zone area.

3.1.2 Concession analysis

In addition to determining the impact of buffer zones on deforestation, I also assess
the impact of the buffer zone designation on the establishment of extractive concessions.
Reducing extraction near sensitive PAs is an original goal of Peru’s buffer zones, and
SERNANP has direct control over the creation of new concessions through the compatibility
decision. First I compare the percent coverage of formal mining concessions created after
2007 (by which time all studied buffer zones had been implemented) within the buffer zone
to the percent coverage in the 10km outside the buffer zone. As in the deforestation analysis,
I also use covariate matching to determine the ATT of buffer zone protection on mining
concessions created after 2007. I also obtained shapefiles for petroleum concessions, but
there were too few within buffer zones and their surrounding areas to conduct the analysis without severe spatial autocorrelation. Mining concession boundaries come from INGEMMET, and only titled concessions were used for the analysis. I did not examine the presence of concessions created before 2007 because SERNANP is not allowed to remove pre-existing concessions in the buffer zone.

Sample observations were taken from corner points of a 1km by 1km grid placed over Peru. I chose 1km as the level of separation between points because mining concessions are granted on a 1km by 1km grid-system. Thus separating points by at least 1km does not allow these cells to be double-counted. Spatial autocorrelation may still be a potential problem, as some miners have the rights to multiple, side-by-side grid cells as part of their concession. However, I also analyzed the pooled data at a 5km level and found the same trend as with 1km separation. I removed all observations located inside of national or regional PAs and buffer zones not part of the study. The remaining points were then populated with the distance to cities with a population greater than 50,000, paved or finished roads, known mineral deposits (freely available online from INGEMMET, the Geological Institute of Mining and Metallurgy in Peru) and rivers (all distances in km); elevation (in m); slope (in degrees); department; a dummy variable for whether the point fell inside a target buffer zone; and a dummy variable for whether the point fell inside a mining concession created after 2007. I matched data as described in section 3.1.1 to estimate the ATT for the 13 buffer zones pooled together and for each buffer zone individually. I also estimate the ATT for mining concessions in the buffers before 2000, which should be negligible if matching is successful in finding an appropriate counterfactual. I calculate the area of mining concessions avoided by multiplying the ATT and the buffer zone area.
3.1.3 Field interviews

I supplemented the land use analysis with field interviews conducted during June – August of 2014 in Lima (11 informants) and in Puerto Maldonado (21 informants), Peru. I use insights from interviews to better interpret my results and reveal political struggles and other unofficial factors shaping management. I interviewed leaders from Peruvian conservation NGOs, government environmental agencies, government extraction agencies, and community groups to gather diverse perspectives on buffer zones (Table 5). Interviews were semi-structured and the questions fell into three main topics: (i) opinions on the legislation and current management of buffer zones, (ii) perceived impacts of buffer zone on conservation and development, and (iii) suggestions for improving buffer zone effectiveness (see Appendix for specific questions). In order to protect the anonymity of informants, I omit names here and only include the informant’s affiliation if s/he gave me express permission to do so, as enforcement and corruption are potentially sensitive issues. To improve the ease of reading, I will use interview codes (see Table 5) to cite information learned from field interviews. These codes begin with “I-L” for interviews in Lima and “I-PM” for interviews in Puerto Maldonado, followed by a “G” for an informant from a government agency and “NG” for an informant from a non-governmental agency.

3.2 Results

Of the 13 buffer zones studied, only two have a higher rate of deforestation inside the buffer compared to the 10km area surrounding the buffer (Figure 3). Five of the 11 have limited deforestation for more than 0.5% of their area. However, this analysis is vulnerable to
biases in the location of buffer zones. To account for those biases, I employed statistical matching to define a more appropriate counterfactual. Matching improved covariate balance between the treated (buffer zone) and control (outside area) groups for all seven covariates (see Table 6). While only results from the pooled match are shown here, these are consistent with matching of individual buffer zones. The results of the matching are presented in Figure 4. I find that the 13 buffer zones have a pooled ATT (average treatment effect on the treated) of −0.38% on deforestation, and that this negative trend is highly significant. When I perform matching on each of the 13 buffer zones separately, I find that only five are significantly reducing deforestation: Ashaninka/ Otishi/ Machiguenga, Rio Abiseo, Tabaconas Namballe, Yanachaga Chemillen, and Yanesha/ San Matias San Carlos. One buffer zone, around Tuntanain national park, is actually associated with a higher rate of deforestation, albeit only by 0.31%. The Yanesha/ San Matias San Carlos buffer showed the largest impact on deforestation, with an ATT of -2.57%. The range in values suggests that while buffer zones in this study have a relatively small impact on deforestation overall, certain buffer zones are significantly reducing deforestation. Figure 5 shows the amount of deforestation expected in the absence of buffer zones according to the matching analysis. In short, the buffer zones appear to have prevented 320 km² of forest loss during the study period.

The results from comparing inside and outside deforestation rates are fairly consistent with the matching analysis, as the five significant results from matching also show high rates of avoided deforestation in the simple analysis. The exception is the Tambopata/ Bahuaja Sonene buffer, which shows a large impact on deforestation in the inside/ outside analysis, but no significant difference when compared to the match control group. This effect may be the result of the location of the district capital, Puerto Maldonado, within 10km of the buffer.
zone edge. Thus the surrounding area would have a higher deforestation rate than the buffer zone in the simple analysis, but controlling for distance to Puerto Maldonado showed the buffer zone did not slow deforestation.

Deforestation is an important facet of buffer zone effectiveness, as it points to the amount of resource use occurring in the buffer zone, something the legislation attempts to limit. However, buffer zone managers are not charged with preventing all deforestation, and/or they might not be able to control certain illegal activities. To estimate the impact of SERNANP’s decision-making power on extraction in the buffer zone, I analyze the issuance of mining and petroleum concessions. I did not perform matching or compare coverage of petroleum concessions due to spatial autocorrelation, and because there was so little overlap between concessions and buffer zones. In fact, only one petroleum concession created after 2007 overlapped with one of the target buffer zones (Yanesha – San Matias San Carlos), and there was only 12 km² of overlap. The surrounding 10 km of the buffer zones overlapped an additional two concessions totaling 110 km². Figure 6 presents the coverage of new mining concessions in buffer zones compared to the surrounding area. In all 11 of the areas with mining concessions present, the percent coverage of concessions is higher in the surrounding area than in the buffer zone. Between the 13 buffer zones, there were 391 mining concessions created after 2007 within the buffers, and 1464 in the surrounding 10 km. The sizes of the concessions in the buffer zones were slightly larger (457 ha in the buffer vs. 421 ha outside, p=0.05). Thus the difference in area can be attributed to fewer concessions granted within buffer zones.

Similar to the deforestation analysis, I also perform covariate matching on the area of mining concessions issued after 2007 to reduce the impact of covariates. Again, matching
improved balance for all covariates (Table 7). The overall ATT in this case is −2.90%, which is significant at the 0.001 level (Figure 7). I also performed matching on mining concessions created before 2000, when none of the buffer zones were yet created, as assurance that buffer zone areas did not already have fewer concessions. Indeed, the impact on mining concessions before 2000 is +0.4% (p<0.001). While this result is significant, the estimate is negligible compared to the ATT after buffer zone creation. Thus we can surmise that the estimate of buffer zone impact is due to buffer zone designation, not pre-existing differences. When looking at the 13 buffer zones individually, 10 are found to significantly reduce the area granted in mining concessions since 2007. The other three (Allpahuayo Mishana, Alto Purus, and Purus) have ATT values near zero, but are not located in areas of heavy mining. Three buffer zones (Ichigkat Muja, Tabaconas Namballe, and Tambopata/ Bahuaja Sonene) reduce the coverage of mining concessions by over 10%. While two of these three do not show a significant impact on deforestation, the legislation is making a major difference in the number of concessions issued within the buffers. Figure 8 shows the area of avoided mining concessions within each buffer zone; mining concession area since 2007 was 1739 km² less than expected in these 13 buffer zones. Thus it appears that buffer zones regulations are reducing the amount of land granted in formal mining concessions adjacent to parks and reserves. However, the lack of concessions does not always ensure a lack of mining; for example, the illegal mining site “La Pampa” has caused ~30 km² of deforestation in the Tambopata/ Bahuaja-Sonene buffer although there are no mining concessions in this area (Figure 10).
3.3 Discussion

3.3.1 Interpreting buffer zone effectiveness

The results from the mining concession issuance and deforestation analyses suggest that buffer zones are successful on some measures. Since their establishment, buffer zones appear to be significantly limiting the area of new mining concessions within their boundaries, and reducing deforestation in some cases. Pooling the data on 13 buffers showed a near-zero impact on deforestation, but examining them individually brought forward that five did have a significant impact on forest loss (Ashaninka/Otishi/Machiguenga, Rio Abiseo, Tabaconas Namballe, Yanachaga Chemillen, and Yanesha/San Matias San Carlos). Interestingly, these five buffer zones are all located at higher elevations, in the transition between the Andes and the Amazon (Figure 2). Other studies have shown that the highest rates of deforestation in the Peruvian Amazon occur in this transition area, especially near the city of Pucallpa and the road network emanating from it (Oliveira et al, 2007). In other areas where deforestation is slow, buffer zones do not have the opportunity to be effective; even if the deforestation rate is very low in the buffer, it will not be significantly different from the low rate in the matched sample. If we only look at the buffer zones with a deforestation rate of over 1% in the surrounding area (Figure 3), we find that five of the seven are significantly reducing deforestation. Thus buffer zones are often effective at reducing deforestation in areas where deforestation pressure occurs.

In regards to mining concessions, the percent coverage of new concessions was significantly lower than expected in 10 of the 13 buffer zones. Overall, buffer zone management prevented an estimated total of 1739 km$^2$ of mining concessions within their boundaries, which represents a major success for buffer zones. This reduction of mining
concession area may be confounded by leakage if these concessions were simply displaced outside of buffer zones. However, while leakage can compromise initiatives to reduce forest carbon emissions (e.g. Ewers & Rodrigues, 2008), this displacement may constitute success for a program intended to ‘buffer’ PAs, as harmful extractive activities are relocated away from biodiverse or ecologically important areas (e.g. headwaters). The negative environmental impacts of mining can be observed tens of kilometers from mining sites (Durán et al, 2013) and mining is increasingly associated with tropical deforestation (Alvarez-Berríos & Aide, 2014). The reduction of mining concessions in buffer zones limits these negative impacts in PAs. Indeed, the goal of the legislation is to reduce threats adjacent to PAs, not to reduce mining and oil extraction as a whole.

The lack of new mining concessions in the buffer zones suggests that SERNANP is effectively using the “compatibility” portion of their binding decision, where they may approve or deny new concessions within buffers. Interviews corroborate that SERNANP frequently denies new concessions within the buffer zone, but informants also expressed that they very rarely see an Environmental Impact Study (EIS) within a buffer zone denied during the OTPF stage (I-L-G6, I-PM-NG5). Approval of the EIS may happen because SERNANP attempts to avoid conflict (I-PM-NG5), because some SERNANP employees ignore activities happening outside of their PA (I-PM-NG5), or simply because their concerns are addressed through the iterative process of approving an EIS (I-PM-G3). The changes in the instrument prior to approval may include increased study on the potential impact of the activity to the park, improved monitoring plans, or altered equipment usage. In this way, SERNANP can mitigate the negative impacts of the extractive activity without completely disallowing it. Approval of the EIS would not have an impact on the issuance of mining...
concessions, the variable of interest in this study. However, the approval of an EIS dictates the extent and manner of extraction inside already existing concessions, which may have important ecological implications for the PA.

Petroleum extraction is another growing extractive industry with severe environmental consequences (Finer & Orta-Martinez, 2010), but I was unable to determine the impact of buffer zones on petroleum concessions using matching because of their large size and heterogeneity on the landscape. However, the Peruvian governmental oil organization, PeruPetro, reportedly does not currently create concessions that overlap buffer zones “as a form of precaution” (Isabel Tarfur Marín, personal communication, September 14, 2014). Indeed, I found only 12 km² of overlap between buffer zones and petroleum concessions after 2007. Likely they are choosing to move their concessions to other areas with fewer regulations, although as noted above, this still represents a success for buffer zones if harmful activities are displaced away from PAs. This is particularly impressive given the fact that Ecuador and other neighboring countries still allow petroleum concessions to overlap with national parks themselves (Finer et al., 2008). In Peru, petroleum concessions now do not even have overlap with buffer zones.

The distinction between effectiveness with regards to deforestation and mining concessions highlights the importance of measuring effectiveness using multiple indicators. If this study only examined the impact of buffer zones on deforestation, as is traditional in studies of PA effectiveness, it would miss the significant reduction in formally approved extractive activities. Mining concessions are potentially a stronger indicator of buffer zone performance, since the legislation has direct leverage over concessions, whereas small-scale activities like non-mechanized farming may be allowed that, in sum, cause significant
deforestation. Nonetheless, deforestation near PA boundaries may still concern conservationists given possible impacts on the PA (e.g. Laurance et al, 2012).

3.3.2 Insights from Peruvian leaders

Quantitative analyses are powerful tools for identifying trends and estimating impacts, but reveal less about the political challenges of managing buffer zones. To fill these gaps, I pair the quantitative matching analysis for mining concessions and deforestation with interviews from Peruvian experts in Lima and Puerto Maldonado (the site of my case study, see Chapter 4). In both places, informants expressed that buffer zones are generally effective at slowing down the expansion of formally sanctioned extractive activities, but that they often fail to stop illegal activities. In Puerto Maldonado in particular, all conversations led back to illegal mining within the buffer, which respondents agreed is the primary threat in the region. Over half of my respondents in Lima (n=4) told me that ambiguity over responsibilities and a lack of follow through for these responsibilities have been major challenges to buffer zone management across Peru. This group also blamed buffer zones’ limited capacity to slow illegal activity on low funding for SERNANP and the other involved agencies. Several (n=3) highlighted conflicting opinions and goals within different sectors of the government that complicate management. All NGO and government environmental agency respondents agreed that buffer zones need to be improved. All three NGO employees I talked to in Lima and several more in Puerto Maldonado (n=3) agreed that “the laws are already in place” (I-PM-NG5) to effectively conserve buffer zones, but that management requires improved coordination between the various agencies that have jurisdiction in the buffer zone and increased funding.
Buffer zone impacts on development

As SERNANP limits concessions and resource-use activities in the buffer zone, there may be concerns that buffers are limiting development. According to one informant in the extractive industry, buffer zones have very little impact on the country’s overall economic development, because large corporations can easily shift their operations to other locations if they are hampered by SERNANP’s restrictions (I-L-G6). Small-holders may not have as much of a choice. For example, the small-scale mining community of Apaylom in the buffer zone of the TNR began operations in April of 2005, 8 months before the buffer zone was designated. The community has tried, thus far unsuccessfully, to obtain the approval of SERNANP for its Environmental Impact Statement so that they can continue working. The community is currently operating illegally, and has faced government destruction of its equipment even as it attempts to follow the rules (although this level of conflict over mining is unique to the Tambopata/ Bahuaja-Sonene buffer zone) (I-PM-G13). As one informant in the Ministry of the Environment put it, all protected areas are created with an “original sin”: that the costs and benefits of the PA are unequally distributed and normally are least favorable around the PA, where resource access is limited. In his view, this inequality needs to be addressed via a “baptism”, or initiatives to find new, sustainable, economic alternatives for local people (I-L-G4). While the legislation on buffer zones in Peru includes some language about promoting sustainable resource use, SERNANP does not allocate funds to do so, although some NGOs in the area implement sustainability projects with their own funds (I-L-G4). Respondents believed that buffer zones do not impact economic development as a whole, but may have negative effects on the particular actors whose activities are limited (I-L-G6, I-L-G8, I-L-G10).
Although extractive activities, such as oil and mining, are nearly always deemed incompatible with the objectives of the nearby PA, small-scale agriculture generally is approved in buffer zones (I-L-NG1, I-L-G4). Thus, rather than an attempt to control land use by small-holders, a common critique of national buffer zones in other countries (Neumann, 1997; Heinen & Mehta, 2000), buffer zone policy in Peru focuses more on controlling the extractive industry. Although none of my informants viewed buffer zones as a threat to Peru’s national economic interests, there are clashes between environmental policy and extractive interests in the country. For example, the Minister of Finance recently announced measures to speed up the environmental permitting process for mining and hydrocarbon projects (which affects SERNANP’s decision making) in order to combat an economic slump caused by stalled private investment and a drop in gold and copper exports (Quigley, 2014). In addition, buffer zone legislation gives SERNANP, a branch of the national government, some level of control over areas that are generally managed by the regional government. For example, around 40% of the region of Madre de Dios in southeastern Peru is composed of national PAs, which some view as a threat to development (I-L-G3). With the addition of buffer zones, now over half of the region is controlled to some extent by SERNANP rather than the regional government. Rather than an expansion of the national government into the lands of small-holders, as Neumann described in the buffer zones of Tanzanian parks, in Peru buffer zones may be seen as an expansion of one arm of the government into another’s territory. Bury & Norris (2013) describe territorial competition between conservation and mining frontiers in the Cordillera Huayhuash of Peru; it is possible that buffer zones figure in similar territorial competition for vast areas of the Peruvian Amazon.
Challenges in buffer zone management

The results of this study indicate that buffer zones effectively reduce the number of new mining concessions granted within their boundaries, but have a less consistent impact on deforestation. This difference in impact may reflect a weakness in buffer zone management in preventing damaging illegal activities. While SERNANP has the power to decide which activities are allowed in the buffer zone and with what stipulations, monitoring and enforcement are the responsibility of the regional government and competent government agencies (e.g. the Regional Office of Agriculture for problems related to agriculture) (I-L-NG1). SERNANP does not have any power to monitor or enforce the law within buffer zones (I-L-NG1). In many cases, the regional government and other government agencies do not make buffer zone management a priority, and thus delay responding to buffer zone violations or fail to respond at all (I-L-NG1). Even if these agencies did want to respond, they often lack the funding and personnel to do so effectively (I-PM-G3, I-PM-G8). Several conservation NGO and government representatives commented that buffer zones are effective at stopping some extractive activities from advancing due to SERNANP’s approval process in the compatibility stage (an observation corroborated by my findings), but that they are essentially powerless against illegal activities (I-L-NG1, I-L-NG2, I-L-G4, I-PM-G3). For example, buffer zone management has successfully limited the issuance of mining concessions in the Tambopata buffer zone, but deforestation from illegal gold mining continues unabated (see Chapter 4). As one conservation NGO informant put it, “the problem is that the majority [of activities in the buffer zone] are illegal” (I-L-NG2).

This disjointed management is further complicated by confused agency responsibilities. For example, the Tambopata National Reserve in southeastern Peru is under
threat from an illegal gold mining rush, with one of the foci of illegal mining, La Pampa, cutting through the buffer zone (Asner et al, 2013). Park staff (employees of SERNANP) have the power to reject formal mining concessions within the buffer zone, but are frustrated by the lack of enforcement power they have to combat illegal mining (I-PM-G3). Meanwhile, most regional government officials, who have some level of responsibility over the area, seem to believe that the buffer zone is the competency of SERNANP (I-PM-NG2, see Chapter 4 for further details).

To add to these challenges, there is scarce funding for buffer zone management in SERNANP, for deciding about concessions and promoting sustainable activities, or in the regional government, for monitoring and enforcement (I-L-NG1, I-L-G4). One former park manager remarked, “if you don’t have money to take care of the PA itself… how do you control and police what is outside of your PA?” (I-L-G3). As a result, some PA managers limit their involvement in the buffer zone, which may lead to negative consequences as their PA becomes more isolated in the landscape (I-L-G3, I-PM-NG5). The difference in importance that managers place on buffer zones is reflected in the inconsistencies of SERNANP approval of extractive activities, the delineation of buffer zone boundaries between PAs, and involvement in buffer zone activities (I-L-G3). For example, the Ministry of the Environment wanted to launch a project to create alternatives to illegal mining in the buffer zone of the Tambopata National Reserve. However, as an informant tells the story, the park manager at the time was not interested in problems outside of the park boundaries and did not bother to attend the meeting about the plan (I-L-G3). SERNANP’s decisions are made on a case by case basis, as there are no activities that are designated as allowed or disallowed in the legislation (I-L-NG1, I-L-G3).
Several informants suggested that improving coordination between SERNANP and the entities in the regional government could greatly enhance the effectiveness of buffer zones (I-L-NG1, I-L-G4, I-L-NG5, I-PM-NG6, I-PM-NG16). In addition, one informant suggested increasing the budget for buffer zone management, especially within the regional government (I-L-G4). One informant from SERNANP expressed that the best solution was to include buffer zones within the official park boundaries so that SERNANP would have complete control over activities happening in the buffer zone (I-L-G3). However, over half of the respondents in Lima (n=4) felt that the current structure would be acceptable if responsibilities were more clearly specified, resources were improved, and each agency did its share.

3.3.3 Peruvian buffer zones in context

Defining and measuring effectiveness is complex, and different outcome variables and scales complicate comparisons between studies. Leakage also confounds estimates of effectiveness, although displacement of harmful activities away from PAs may still constitute success for buffer zones. The mixed impact of buffer zones on deforestation has been documented around the world; some studies show a reduction of deforestation inside buffers (e.g. Scullion et al, 2014), but others show no impact (e.g. Mehring and Stoll-Kleeman, 2011). Contrary to the results of this study, Scullion et al (2014) show a reduction of deforestation inside the Tambopata buffer zone (2.19%) using similar methods. The discrepancy may be that the Scullion et al paper uses a smaller study area that contains the worst of the illegal mining or that this analysis measures the impact of the combined Bahuaja-Sonene and Tambopata buffer zone. Compared to studies of PA effectiveness using
matching elsewhere in the tropics, the estimates of avoided deforestation in this study are low (2.6% for the most effective buffer versus 7-9% in Andam et al, 2008; 4-5% in Blackman, 2014; 2-16% in Nelson & Chomitz, 2011). However, it is not surprising that the impact on deforestation of Peruvian buffer zones is less than the impact of PAs, as PAs generally have stricter rules of use and more authority to enforce them. Indeed, the estimate for the Tambopata buffer zone from Scullion et al (2014) is close to the range of effectiveness found in this study.

Scullion et al (2014) also show that deforestation is greater when concessions overlap buffer zones, but the authors do not address why concessions were granted in these areas in the first place, or whether buffer zone managers were actively trying to prevent overlap. Given the proliferation of mining activities in tropical countries and their adverse impacts on PAs, this kind of analysis deserves greater attention.

Overall, buffer zone management is Peru is full of ambiguity and complexity over who has control in these areas and what activities are allowed. In addition, Peruvian buffer zones face a lack of funding and political will against illegal activities. These challenges are consistent with assessments of buffer zones elsewhere. Buffer zones in Peru, Indonesia, and around the world face problems of unclear responsibilities, as buffer zones are often located outside of PA boundaries and outside of the jurisdiction of park managers (e.g. Wells et al, 1992; Mehring & Stoll-Kleeman, 2011). In the Philippines, Lynagh & Urich (2002) demonstrate that providing opportunities for sustainable activities within the buffer zone is not sufficient to prevent poor farmers from illegally clearing land in the buffer or the PA. Buffer zones in Vietnam have also faced problems with illegal logging and extraction within the buffer and the PA (Gilmour & Van San, 1999).
These problems in Peru and other tropical countries have earned buffer zones a poor reputation among conservationists (Wells et al, 1992). However, conservation research regarding the effectiveness of buffer zones or other multiple use areas is too often simplistic. Not only do these studies tend to focus on only one factor of effectiveness (i.e. forest loss), they also oversimplify effectiveness as a simple yes or no question. Instead of testing whether a particular category of PA or type of landscape-level initiative works or not, it is important to address the institutional context of the initiative. Conservation interventions and land use rules are not just technical questions, they reflect competing goals between economic sectors or government agencies and may represent an effort to find compromise. For example, research in Peru and Ecuador has demonstrated that PA implementation is often much more closely linked to local context than to categories or international standards (Naughton-Treves et al, 2006). It is not enough to conclude that a strategy works. Instead, we must dig more carefully into the why and the how. For buffer zones in Peru, the context is full of ambiguity over responsibilities, low funding, and competing interests within different branches of the government. However, despite these challenges, this study demonstrates that the generally dismissed category of “buffer zone” is slowing deforestation and the spread of mining concessions, at least in some sites, due to the decision-making powers of SERNANP.

3.4 Conclusions

Despite disjointed management and low funding, buffer zones in the Peruvian Amazon have a significantly slowed the spread of extractive concessions near parks, and in some cases, also slowed deforestation. Given the major impact of mining and oil extraction
on natural ecosystems, the displacement of concessions away from PAs represents a major success for buffer zones. This result is surprising considering that most conservationists simply dismiss buffer zones because of their unclear responsibility and often lofty goals of sustainable development (e.g. Wells et al, 1992). It appears that some buffer zones may be working in spite of that ambiguity, though there is certainly room for improvement, especially regarding the control of illegal activities. In particular, SERNANP and regional governments need to work more closely to define responsibilities and make sure all parties are fulfilling their duties. In addition, this is a relatively new legislation, with most of the studied buffer zones created in 2005 or 2007. While this study shows promising results for the success of buffer zones in Peru, their ultimate effectiveness will not be apparent for years.

Buffer zones have a huge coverage in Peru of 145,917 km², an area more than double the size of Costa Rica. Buffer zones are similarly extensive in other areas around the world, and thus it is important to continue studying this conservation initiative, especially as it is shown here to have a real impact on environmental outcomes. Buffer zones are an imperfect environmental tool, but so are all methods to reduce environmental damage. Instead of focusing on the flaws of landscape-level conservation initiatives, we must emphasize the ways in which they do currently work, and continue to strive for better policy and management.

This analysis attempts to generalize the impact of buffer zones in the Peruvian Amazon. While it is useful to recognize the magnitude of impact on a national scale, the study necessarily simplified the situation. In order to understand the complexity of buffer zone management, I now turn to a case study in the buffer zone of the Tambopata National Reserve (TNR).
4. Case Study

4.1 Background

I chose the buffer zone of the Tambopata National Reserve (TNR) as the site of this case study because urgent environmental threats in this area reveal the strengths and weaknesses of Peruvian buffer zones. The TNR is located in the region of Madre de Dios in southeastern Peru, at the convergence of the Malinowski and Tambopata rivers. It is considered a national conservation priority area (Rodriquez & Young, 2000); it contains world record diversity in butterflies and birds, and is home to intact populations of several threatened species such as white-lipped peccaries, giant river otters, and jaguars (Foster, 1994). Its buffer zone, designated in 2005, reaches the Interoceanic Highway and the region’s capital of Puerto Maldonado to the north (Figure 9).

This area is now under threat due to a major gold rush and increased access from the Interoceanic Highway, completed in 2011 (Southworth et al, 2011). The wave of alluvial gold mining presents an important test for the buffer zone, as a key purpose of buffer zone legislation is to reduce extractive activities near PAs. The economic downturn in 2008 led to a spike in gold prices (Shafiee and Topal, 2010) which has attracted an estimated 30,000 to 40,000 illegal gold miners from around Peru to Madre de Dios to make their fortune. Illegal gold mining brings in an estimated $3 billion per year to Peru, mostly for gold extracted in Madre de Dios (Cawley, 2013). Miners use machinery (such as chupaderas, hydraulic jets that spray soil with water to sort out clumps of dense gold) to extract gold from alluvial deposits, often clearing forest along the way. Since 1999, 50,000 ha of forest have been cleared by mining in the region of Madre de Dios, about half by small scale mining.
operations (Asner et al, 2013). Mercury use is also increasing exponentially in the region (Swenson et al, 2011), primarily as a method for cleaning the gold. Researchers have found unhealthy levels of mercury accumulation in humans in the Madre de Dios region due to bioaccumulation (Ashe, 2012). In addition, illegal gold mining has created human rights abuses in the region, including forced labor, unsafe and sometimes violent working conditions, and sex trafficking of young girls (Verite, 2013).

In 2006, a new major mining site, known as “La Pampa”, emerged and now runs straight through the Tambopata buffer zone (Figure 10) (Asner et al, 2013). Recent research suggests that the buffer zone is still reducing deforestation despite the surge in gold mining, but that deforestation rates are much higher within mining concessions that overlap with the buffer (Scullion et al, 2014). In this study, I aim to build upon this research to determine the impact of the buffer zone on the creation of mining concessions in the first place and examine how well the buffer zone prevents illegal activities. I use statistical matching to determine buffer zone impacts on mining and other concessions as well as deforestation. I also use qualitative interviews to shed light on what aspects of management are working or not in this case and provide guidance for improving buffer zone implementation in this sensitive region.

4.2 Methods

4.2.1 Deforestation analysis

To evaluate the impact of Tambopata buffer zone on forest loss I use covariate matching to produce an unbiased estimate. The buffer zone surrounding the Tambopata
National Reserve is contiguous with the buffer of Bahuaja-Sonene National Park. While these buffers are legally one entity, park managers from the TNR only make decisions in the part closest to the reserve. With assistance from TNR staff, I drew the boundary between the western edge of the reserve and the town of Santa Rosa Baja. I only use the Tambopata portion of the buffer zone for the deforestation and concession analysis since I am interested in the area most affected by the mining and in the jurisdiction of the TNR. Then, I developed my sample by using a 1km by 1km grid in the region of Madre de Dios and using corner points as my observations. I chose 1km as my sampling distance to reduce spatial autocorrelation and data volume. Points that had less than 50% forest cover in 2000, were deforested before the buffer zone was established, or were located inside another PA or buffer zone were removed from the sample.

Once the sample was complete, I generated the outcome and treatment variables and the covariates for each point. The outcome variable is a dummy for deforestation between 2005 (the year of buffer zone creation) and 2012, from the Hansen et al (2013) dataset on Forest Loss Year. The treatment variable is a dummy for whether or not the point falls within the Tambopata buffer zone. The covariates are distance to Puerto Maldonado, distance to paved or finished roads, distance to rivers, distance to the forest edge, distance to placer gold deposits, slope, elevation, and agricultural suitability (see section 3.1.1 for more explanation of these covariates and how they were chosen). All variables were joined to the sample points in ArcGIS 10.1 and exported as a csv file for use in R 3.1.0. I use Sekhon’s (2011) Matching package for R to conduct covariate matching based on Mahalanobis distance for the eight covariates. The results presented are the “average treatment effect on the treated” (ATT),
which is the percentage of deforestation that would likely have occurred in the absence of the buffer zone.

4.2.2 Concession analysis

Deforestation is an important and easily-measured indicator of environmental impact, but is not a direct goal of Peruvian buffer zone legislation. Instead, the law sets up buffer zones to rein in the oil and mineral activities that may negatively affect PAs. To understand whether the buffer zone is impacting these activities, I measure whether the Tambopata buffer zone is reducing harmful extractive activities and increasing more sustainable ones. The Peruvian concessionary system governs a variety of economic activities, thus I employed statistical matching on all concessions created after the buffer was established in 2005, including mining, petroleum, reforestation, ecotourism, and conservation concessions (where concessioners have rights to conserve or preserve the land). Most buffer zone managers would like to avoid the first two types of concessions and promote the other three. I excluded wood concessions, agricultural titles, and Brazil Nut concessions because there were negligible concessions granted after 2005 for the first and because I did not have sufficient data for the latter two.

As in the deforestation analysis, I also used a 1km by 1km grid in Madre de Dios to generate sample points. This helps reduce spatial autocorrelation from the concessions. For example, mining concessions are granted in 1km by 1km cells, thus this technique assures that each cell is only sampled once. Again, all cells were populated with the relevant variables: a binary for whether the point was inside the buffer zone, distance to Puerto Maldonado, distance to roads, distance to rivers, slope, elevation, and distance to gold.
deposits (important in this region because of the large-scale impact of legal and illegal gold mining). In this analysis, the outcome variables are dummies for whether the point falls inside one of the five types of concessions (mining, petroleum, reforestation, ecotourism, and conservation). I used only concessions that were created after buffer zone creation in 2005, since pre-existing concessions did not undergo the approval process by SERNANP. Shapefile sources are described in Table 4. Matching was performed as related in section 4.3.1. Results are reported as the average treatment effect on the treated (ATT).

4.3.3 Field interviews

I supplemented the land use analysis with field interviews conducted during June – August of 2014 in Lima (11 informants) and in Puerto Maldonado (21 informants), Peru. I use insights from interviews to better interpret my results and reveal political struggles and other unofficial factors shaping management. I interviewed leaders from Peruvian conservation NGOs, government environmental agencies, government extraction agencies, and community groups to gather diverse perspectives on buffer zones (Table 5). Interviews were semi-structured and the questions fell into three main topics: (i) opinions on the legislation and current management of buffer zones, (ii) perceived impacts of buffer zone on conservation and development, and (iii) suggestions for improving buffer zone effectiveness (see Appendix for specific questions). In order to protect the anonymity of informants, I omit names here and only include the informant’s affiliation if s/he gave me express permission to do so, as enforcement and corruption are potentially sensitive issues. To improve the ease of reading, I will use interview codes (see Table 5) to cite information learned from field interviews. These codes begin with “I-L” for interviews in Lima and “I-PM” for interviews
in Puerto Maldonado, followed by a “G” for an informant from a government agency and “NG” for an informant from a non-governmental agency.

4.3 Results

The deforestation analysis yielded an ATT of 0.11% (SE of 0.68%), which is not significant at the p=0.05 level. Thus the Tambopata buffer zone apparently is not slowing deforestation. The concession analysis yields a slightly more optimistic picture. New mining and petroleum concessions cover less area than expected by >20% each in the buffer zone. Conservation concessions cover slightly less area in the buffer zones than expected, and ecotourism and reforestation concession creation is increased in area by the buffer zone (Figure 11). The size of mining concessions inside the buffer zone is not significantly different from those outside the buffer zone, which suggests that buffer zone management reduced the number of concessions created within the buffer rather than their size. These results point towards important trends in this area, but should not be seen as absolute, since concessions can be very large and cause problems with spatial autocorrelation. Nonetheless, it appears that the buffer zone is associated with fewer concessions potentially harmful to the adjacent reserve. On the other hand, ecotourism and reforestation concessions are more prevalent in the buffer zone than expected.

Beyond the concession results, a key lesson from Tambopata is that the legal zoning of land may not reflect actual land use. Although the buffer zone reduced the number of formally approved mining concessions created within its boundaries, around 20% of deforestation in the buffer zone from 2005-2012 is associated with illegal mining in La
Pampa, with more deforestation occurring in smaller-scale mining sites. Thus, although new extractive activities are for the most part legally excluded from the buffer zone, illegal mining is causing significant environmental damage in the same area.

4.4 Discussion

4.4.1 Is the buffer zone working?

The negative impact of the Tambopata buffer zone on the area of new mining and petroleum concessions and the positive impact on ecotourism and reforestation concessions suggest that SERNANP is effectively using its authority to spatially organize activities relative to the reserve. The buffer zone may simply be displacing mining and petroleum concessions elsewhere in the Peruvian Amazon if companies seek areas with fewer restrictions for extractive activities. Nonetheless, the buffer zone could be deemed ‘effective’ in that potentially harmful activities are displaced from the reserve edge, and potentially beneficial activities are attracted. Caution is warranted when drawing inferences about the fate of biodiversity from observed patterns of formal compliance in concessions. Aside from the conspicuous failure to curb illegal mining, some of the seemingly pro-biodiversity concessions promoted in the buffer zone are not managed according to official goals. In other words, concessions that are ecologically beneficial on paper may have negative impacts on the buffer zone and the reserve. For example, reforestation concessions, granted in the buffer zone in a flurry in 2005 and 2006, are supposed to encourage reforestation of degraded areas. The terms of the concession paradoxically allow the concessionaire to log before reforesting. In some cases, reforestation concessions were granted in primary forest (de Jong,
2009). Thus instead of increasing the connectivity of the landscape by reforesting, these concessions more often than not degrading forested land (I-PM-G12, I-PM-NG17).

Despite slowing the spread of harmful concessions and attracting potentially beneficial ones, I find no impact of the buffer zone on deforestation. This result is contrary to the findings of Scullion et al (2014), who found a reduction of ecosystem conversion of 2.19% within the Tambopata buffer zone in a similar time period (2006 to 2011 in his study, 2005 to 2012 in this study). The discrepancy most likely arises from differences in the study area: the Scullion et al paper confines analysis to an area of ~2 million ha very near the buffer zone that includes the worst areas of mining (Guacamayo, Delta-1, and Huepetuhe), while this study matched buffer zone pixels to similar pixels across the entire region of Madre de Dios (~8 million ha). This study also included the distance to gold deposits as a covariate, an important determinant of deforestation in this area.

One possible explanation for the negligible impact on deforestation is that trees are cleared by small-scale activities that are officially allowed in the buffer, such as subsistence agriculture. Even more likely, deforestation is associated with the rampant illegal mining taking place in Madre de Dios and inside of the buffer zone itself. Small-scale, artisanal mining conducted by thousands of individuals is responsible for much of the deforestation in the region, estimated as 50,000 ha since 1999 (Asner et al, 2013), including a large swath of deforested land in the buffer zone called “La Pampa” (Figure 10) (I-PM-G14). The destruction is concentrated between km 98 and 120 of the Interoceanic Highway, and experts estimate as many as 20,000 miners are working within this area (I-PM-G3). It appears that the Tambopata buffer zone may work at preventing legal activities, but is essentially powerless against illegal ones.
4.4.2 Insights from interviews

All of the 21 individuals I interviewed in Puerto Maldonado brought up illegal mining in La Pampa as a major problem in the Tambopata buffer zone. Many faulted ambiguity in institutional responsibilities, corruption in the regional and national government, or the absence of the state outside of Puerto Maldonado for failing to stop the rush of gold mining in the buffer zone. Members of the NGO community in particular felt that the various government offices responsible for buffer zone management need to coordinate better against this threat. Aside from La Pampa, many respondents believed that the buffer zone encouraged sustainable activities and was effectively reducing harmful activities.

The interviews highlight the involvement of a variety of actors involved in buffer zone management. SERNANP, of course, has the ability to decide what activities are officially allowed in the buffer zone. Then various branches of the regional government are responsible for monitoring and punishing those violating the buffer zone rules within their concession. ONSINFOR, a branch of the national government that monitors forest-related concessions, also plays a role in monitoring and fining rule-breakers. Criminal offenses (such as illegal mining) are handled by the Ecological Police and the Public Prosecutor’s office. Finally, communities living within the buffer zone play a role in monitoring. Most notably, the volunteer Management Committee of the TNR has set up an early alert system within the buffer zone. These diverse actors and their responsibilities and actions within the Tambopata buffer zone are further described in this section.
Issues of responsibility and control in the buffer zone

The fact that the Tambopata buffer zone affects legal concessions but not illegal deforestation matches the legislation. The reason illegal activities are not confronted is at least partially related to ambiguity in buffer zone law. While the law clearly lays out the process for obtaining a concession in the buffer zone with SERNANP’s approval, it is more ambiguous about monitoring and enforcement (I-PM-G2). SERNANP does not have jurisdiction in the buffer zone besides granting the OTPF; if they discover illegal activities within the buffer zone (e.g., during their patrol of the TNR boundary), they do not have the authority to sanction those involved, but instead must report the activities to the “competent agency” (I-PM-G3). The competent agency depends on the type of concession present: DRA (Regional Office of Agriculture) for agricultural titles, DRFFS (Regional Office of Forestry and Wildlife) for forestry and reforestation concessions, and DREMH (Regional Office of Energy, Mines, and Hydrocarbon) for mining and petroleum concessions (I-PM-G12). Unfortunately, these agencies are often very slow to respond to reports of illegal activity (I-PM-G3).

Part of the problem is confusion over agency responsibilities in the buffer zone. Conservationists worry that regional government staff erroneously assume that SERNANP is entirely in charge of the buffer zone just as it is in charge of the TNR (I-PM-G2). Yet the three regional government agency staff members I interviewed indicated they do understand their agency’s responsibilities, but are unable to follow through with them. In one interview, a respondent from DREMH claimed that buffer zones are the competency of SERNANP, but then later into our conversation admitted that DREMH should by law monitor their concessions in the buffer zone, but doesn’t have the budget to do so (I-PM-G8). Another
A regional government agency cited a lack of personnel as the main limiting factor for performing vigilance inside the buffer zone (I-PM-G9). In the Regional Office of Forestry and Wildlife (DRFFS), an informant told me that DRFFS tried to get involved in monitoring and punishing concessioners who allow mining on their land, but concessioners complained to other branches of the regional government that DRFFS was overstepping its authority. After that incident, DRFFS stopped vigilance in order to prevent backlash (I-PM-G10). In addition, even when they caught the perpetrators, it was nearly impossible to request criminal procedures without a DNI (national identity card), which illegal miners often do not have (I-PM-G10). The informant also commented:

“The [national] government doesn’t create the mechanisms or systems so that the regional offices, like us, have the strength and capacity to take actions… to fine, penalize or send [offenders] to the public prosecutor. They don’t give us logistics, there is not funding… they are giving us more responsibilities without any budget” (I-PM-G10)

Rather than not knowing their responsibilities, it appears that these branches of the regional government are trying to pass responsibility off on one another or to SERNANP (I-PM-NG11) because they are unable to perform their duties. Other informants indicated that regional agencies do not take concrete action because some of their employees are complicit in illegal mining (I-PM-NG7).

The one agency that actively monitors and enforces conservation rules within the buffer zone is the Supervision Organization for Forestry and Wildlife Resources (OSINFOR), an organization of the national government with an office in Puerto Maldonado. This office ensures that approved forest-related concessions are following their Management Plan, a very important task in La Pampa, which significantly overlaps reforestation
concessions (Figure 10). Most of OSINFOR’s activities are in response to complaints within concessions; they have visited 41 of 52 reforestation concessions within the buffer zone (I-PM-G12). When OSINFOR discovers illegal mining or other illegal activity within a concession, they first try to determine whether or not the concessioner is involved. In most cases, if the concessioner did not file the complaint themselves, they are most likely complicit in the illegal operation (i.e. participating in the mining themselves, or charging miners a fee to mine on their land) and are levied a fine between $120 and $740,000 depending on the seriousness of the infraction, and in extreme cases the concession is cancelled (I-PM-G12). Of 52 reforestation concessions in the buffer zone, 20 concessioners have been fined and 4 concessions have been cancelled. When other actors are causing the infraction (either with or without the concessioners compliance), OSINFOR turns them over to the Public Prosecutor for criminal procedure (I-PM-G12). However, the Public Prosecutor cannot act without DNI information, and the office has very limited human resources. There are only two prosecutors in the region, and one must travel almost 500km to the nearest court in Cusco half of each week (I-PM-G15).

With the confusion over responsibilities and lack of resources, and the billions of dollars of profits associated with illegal mining, it is unsurprising that the Tambopata buffer zone has failed to prevent illegal mining. SERNANP does not have any power to enforce the law within the buffer zone, and very few agencies are doing their part to sanction illegal activity. Thus the Tambopata buffer zone is just as vulnerable as the rest of the region to the onslaught of illegal gold mining.
Problems with the government’s response to illegal mining

The national and regional governments have taken action to try to reduce illegal mining in Madre de Dios as a whole. Since 2010, the national government has released 7 new Legislative Decrees targeting illegal mining (I-PM-NG7). Most notably, these decrees declared everything outside of the “Mining Corridor” to the north of the Interoceanic highway as a mining exclusion zone (meaning no new concessions) (I-PM-G2), made gold mining without a concession a criminal offense punishable by 5-8 years in prison (I-PM5), and created a new process for formalizing a mining concession (I-PM-G2). At least unofficially, there is a distinction between “informal” miners, who are working towards formalizing their concession, and “illegal” miners, who operate outside of mining concessions and often on other people’s land (I-PM-G14). Both regional and national governments undertake “interdictions” to inhibit illegal mining. The Ministry of the Interior in Peru stages major interdictions around every 15 days, where the National police destroy the equipment of illegal miners from helicopters (I-PM-NG5, I-PM-G15). The Ecological Police of the Madre de Dios regional government also undertake their own interdictions around once a week. These operations are mostly conducted on foot and aim to destroy mining equipment, since arresting miners themselves can be difficult and potentially dangerous (I-PM-G15). In June of 2014, then Head of the High Commission for Mining Formalization Daniel Urresti told the press that “illegal mining in this zone has been completely eliminated” (“Madre de Dios”, 2014).

Despite the alleged control of the situation, illegal gold mining is still widespread in Madre de Dios and within the buffer zone in particular. All 21 of my respondents, who I interviewed in August of 2014, refuted Mr.Urresti’s claim that illegal mining is no longer an
issue. Indeed, a recent study by the Amazon Conservation Association found 226 ha of mining-related deforestation in the buffer zone cleared in a four month period between October 2014 and February 2015 (“Madre de Dios”, 2015). One problem is that lawmakers in Lima are often unaware of the situation on the ground and make laws that are not applicable and difficult to enforce (I-PM-NG11). For example, the formalization of mining titles is a good idea in principle, as miners must prove their rights to the concession and seek approval from various agencies. However, the formalization process is almost impossible to carry out; despite many NGOs and agencies working to help miners, not a single one had been formalized in Madre de Dios as of August 2014 (I-PM-G2). In addition, although illegal mining is now a criminal offense, only three miners have been sent to prison, and all of them left early allegedly due to corruption and/or contradictions between laws (I-PM-NG5).

The government interdictions are not successful in part because they do not include regular monitoring or oversight. As one informant put it, “what military comes in to conquer an area and then leaves?” (I-PM-NG11). Corruption is also a major issue, as gold miners have a lot of financial and political power. The miners are almost always warned about national government interdictions days before they happen, and hide or move their equipment. The national police come in and destroy the old mining equipment that has been left behind, and the “miners come right back to retrieve their equipment and continue working” (I-PM-NG17). The interdictions by the regional Ecological Police and the public prosecutor’s office are generally more of a surprise to miners, but also much smaller (I-PM-G14). In addition, these operations are constrained by the availability of public prosecutors, who must be present for this kind of legal intervention. As one of the two prosecutors travels to Cuzco for half the week, the frequency and impact of these interventions are limited.
Many members of the conservation NGO and management community are frustrated by the unsuccessful attempts to control mining, and some believe that the national and regional governments are complicit in the illegal mining rush. Said one informant, “how can you solve a problem if your own people, those that are accompanying you and carrying out the actions are the direct accomplices of the [illegal miners]?” (I-PM-NG7).

Community efforts in the buffer zone

Despite problems with buffer zone governance and massive deforestation from illegal mining, many NGO employees seemed to think that the buffer zone is effective in terms of promoting forest-friendly activities outside of La Pampa, not necessarily due to government action, but rather thanks to the efforts of the people who live there (I-PM-G2, I-PM-NG11, I-PM-NG16). Buffer zone residents tend to be people who have lived in the area for several generations and who are committed to conserving the forest (I-PM-NG5). Some are also able to capture economic benefit of the forest. For example, a road stretching east from Puerto Maldonado has become a “Tourist Corridor” with many local residents owning small eco-lodges or environmentally friendly homes and farms. Another example comes, paradoxically, from small-scale mining communities on the Malanowski River bordering the reserve. These mining communities, such as Manuani, Apaylom, and Amataf, have been around since before the buffer zone was created, and serve as a block for illegal miners hoping to enter the reserve (I-PM-NG6, I-PM-G13). However, there are still concerns about these groups mining so close to the reserve.

The most salient example of community involvement in the buffer zone is the Management Committee, headed by Victor Zambrano (I-PM-G2). All Peruvian national PAs
have Management Committees, groups of community members that work with the reserve staff on the PA’s Master Plan, but the Tambopata Management Committee is among the most active in Peru (I-L-G3). In addition to contributing to the Master Plan for the TNR, the Tambopata Management Committee is also involved in combatting illegal activities in the buffer zone. All members of the Committee are members of the community who volunteer their time to aid in the management of the TNR and its buffer. A particularly noteworthy achievement of the Management Committee has been, with the help of several local NGOs, to organize a “Vigilance Network” inside the buffer zone. They train local people to use cameras, GPS, etc. to document environmental infractions, particularly illegal mining, inside the buffer zone. These reports are then given to the Ecological Police and the Public Prosecutor’s office to take action if necessary (I-PM-NG7), and are also posted online for transparency and rapid responses (www.alertaambiental.pe). Of course, the Tambopata Management Committee faces the same limitations as other actors within the legal criminal framework. However, one employee of a local NGO said that this network is effective in a large part due to the dedication of Victor Zambrano (the committee chair). For example, if the Ecological Police are unable to operate because they do not have a truck available, Mr. Zambrano will go door to door to try to borrow one (I-PM-NG17).

Improving buffer zone management and legislation

While the Tambopata buffer zone is effectively slowing the spread of harmful legal activities and attracting beneficial ones within its boundaries, there is much that can be improved to curtail illegal activities, gold mining in particular. Some interviewees stated that the current framework is sufficient, but that regional agencies need to be held accountable for
their duties in the buffer zone and that there needs to be more coordination between agencies over the buffer (I-PM-NG5, I-PM-NG6, I-PM-NG16). However, some are concerned that SERNANP is not well attuned to problems outside of the reserve, and that they should focus more in the buffer zone (I-PM-NG5). Others wanted to expand the role of SERNANP, either by strengthening their role in monitoring and enforcement (I-PM-NG5) or by expanding the reserve to cover at least La Pampa (I-PM-G3, I-PM-NG7, I-PM-G15). One informant said that giving SERNANP control over the buffer zone “is the only way” to halt widespread destruction, since the TNR seems to be the only place spared by the gold rush (I-PM-G15). Another opinion is to involve the local community more into management and decision making, including providing funding for the Management Committee to increase operations (I-PM-G2). Buffer zones are supposed to provide sustainable development opportunities, but at this point these initiatives are limited (I-PM-NG17).

More fundamentally, illegal mining has become such a problem in the buffer zone and in Madre de Dios as a whole because of limited government presence outside of population centers and widespread corruption. The best way to address the current problems of the buffer zone is for the national and regional government to take concrete action against mining and those officials who are complicit with the miners. However, some groups of miners have backed the campaigns of current President Humala and are very involved with the regional government (I-PM-NG7). It is unlikely that this region will see a decrease in illegal mining in the near future given the lack of political will to truly end illegal mining, the massive profits that illegal mining has brought to Madre de Dios (estimated at $3 billion annually in Peru, mostly in Madre de Dios), and the absence of the state in more remote regions of the buffer.
4.4.3 The Tambopata buffer zone in context

The major impact of the gold mining rush on conservation initiatives in Madre de Dios has been documented by other authors. Swenson et al (2011) and Asner et al (2013) point to the massive deforestation caused in the region during the last decade due to illegal mining. Unsurprisingly, other studies of conservation effectiveness in the area cite mining concessions (Scullion et al, 2013) and illegal mining (Vuohelainen et al, 2012) as threats to the conservation integrity of the TNR and its buffer zone. This study corroborates the findings that mining has a negative impact on the buffer zone, but goes further to reveal that management of the Tambopata buffer zone is at least following the letter of the law by slowing the spread of legal concessions. SERNANP is effectively controlling concessions created within the buffer zone, but the current system is unable to handle illegal extractive activities with such high profits and political backing.

The Tambopata case highlights several of the challenges described in the literature on buffer zones and other multiple use areas surrounding PAs, most notably ambiguity over agency responsibilities and difficulty controlling illegal activities. In the Lore Lindu Forest Reserve in Indonesia, the buffer zone failed in part due to unclear responsibilities (Mehring & Stoll-Kleeman, 2011). Similar to this study, the reserve staff claimed that the buffer zone was the responsibility of the local government, while officials in the local government claimed that there were no set rules of responsibility (Mehring & Stoll-Kleeman, 2011). Wells & Brandon (1993) cite a major issue with the buffer zone concept generally as the lack of “legal authority, jurisdiction, and mandate to establish or manage buffer zones” (p. 159) on the part of PA managers. Indeed, SERNANP’s limited capacity to monitor and enforce the law in buffer zones has contributed to the major impact of illegal mining. Illegal use of buffer
zones has also been documented in other places. In the Philippines, Lynagh & Urich (2002) demonstrate that providing opportunities for sustainable activities within the buffer zone is not sufficient to prevent poor farmers from illegally clearing land in the buffer or the PA. Buffer zones in Vietnam have also faced problems with illegal logging and extraction within the buffer and the PA (Gilmour & Van San, 1999). However, both of these cases involve poor local communities and are not occurring at the scale of the gold rush in Tambopata.

Buffer zone management is complex in Peru and around the world, especially when authorities are not clearly specified and there are strong incentives to illegally use resources. However, given recent emphasis on landscape-level conservation, the buffer zone concept should not be abandoned. Rather, conservationists should work to improve existing buffer zones that have much of the groundwork laid for long term conservation. In the case of the Tambopata buffer zone, clarifying responsibilities and enabling actors to follow through with them could curtail the gold rush that is laying waste to part of the buffer zone. Buffer zones have an important role to play in increasing connectivity and preventing PAs from becoming isolated; by continuing to study and improve them, conservationists stand to gain an important tool for landscape-level conservation.

4.5 Conclusions

Although the Tambopata buffer zone is effectively inhibiting the number of mining and petroleum concessions created in the buffer and increasing potentially beneficial concessions, it has been essentially powerless against the wave of illegal mining within its borders. This problem demonstrates the weakness of the Peruvian buffer zone system in
addressing illegal activities. Responsibility of the buffer zone is unclear or at least poorly implemented, corruption undermines efforts to reduce illegal activity, and the criminal system is not properly equipped to handle environmental problems at this scale. The regional and national government must develop the political will to fight illegal mining in order to reduce this issue in the long run. Other steps to improve the buffer zone in the short term include coordinating agency activities, giving more power to SERNANP, and increasing community involvement in the buffer zone. It is my hope that the involved agencies use this information to minimize the damaging impact on the TNR. Overall, the buffer zone has some tools to better protect the PA, but it vulnerable to onslaughts of illegal activities that may cause irreversible damage to the buffer and to the PA.
5. Conclusion

Despite low funding, uncertain responsibilities, and ambiguous rules of use, buffer zones in the Peruvian Amazon are successfully reducing the spread of mining concessions and in some cases, deforestation. The Tambopata case in particular, where illegal mining activity is rampant, demonstrates that buffer zones have an impact on legal activities but are essentially powerless against illegal activities. SERNANP has direct control over legal activities, but monitoring and punishing illegal activities is the responsibility of other regional government agencies, which often have little funding for monitoring and do not make buffer zones a priority. This discrepancy explains why buffer zones consistently reduced mining concessions but only sometimes reduced deforestation within their boundaries. To combat this problem, I suggest that the Ministry of the Environment attempt to clarify responsibilities in the buffer zone and capacitate regional government authorities to act within the buffer against illegal activities.

In addition to changes in buffer zones in Peru, I hope this study will ignite interest in using concessions as an indicator of effectiveness. While forest loss is traditionally used in studies of PA and conservation effectiveness, it is not the only important factor. In the case of buffer zones, which have direct power to reduce concessions within their boundaries, looking at concessions may be a more appropriate measure of the legislation working. Mining and other extractive activities have negative environmental impacts that may threaten the integrity of conservation but are not always apparent in studies of deforestation impact.

Finally, I hope this study will encourage conservationists around the world to reconsider buffer zones as an important tool in landscape-level conservation. Buffer zones
cover an enormous area in Peru and in other countries around the world. Rather than ignore these areas as a lost cause due to ambiguity, overly ambitious goals, and poor funding, conservationists should look more carefully into whether buffer zones are working and how they can be improved. In Peru, buffer zones are reducing harmful activities despite myriad problems, and the legislation is already in place to increase the impact of buffer zones on illegal activities – if PA staff and regional authorities are properly equipped to manage buffer zones, this system can be improved to have even greater impacts. I believe there is great potential for conservationists to leverage existing buffer zone systems to achieve greater connectivity and healthier ecosystems at a landscape-level. By embracing and improving ubiquitous but often dismissed conservation tools, we can supplement existing PAs to better conserve the world’s landscapes.
6. Resumen

6.1 Introducción y metodología

En todo el mundo, los conservacionistas se están dando cuenta de que las áreas naturales protegidas (ANP) no son suficientes para llevar a cabo la conservación de los recursos naturales. En respuesta a este problema, se está aumentando el énfasis en la conservación a nivel del paisaje. Un ejemplo de una iniciativa de este tipo es la zona de amortiguamiento (ZA). Las zonas de amortiguamiento son áreas alrededor de las ANP que tienen como objetivo la conservación y el desarrollo económico. En Perú, estas ZA son parte de la política nacional, y cubren más del 10% de la superficie del país (145,917 km²). El SERNANP (Servicio Nacional de las Áreas Naturales Protegidas) tiene el poder de dar una opinión previa vinculante sobre las actividades que usan los recursos naturales en las ZA (tales como concesiones nuevas y los Instrumentos de Gestión Ambiental), pero no tiene la jurisdicción para supervisar ni fiscalizar. Las ZA tienen como meta reducir las amenazas que puedan “poner en riesgo el cumplimiento de los fines del ANP”, como las actividades de minería y la extracción de hidrocarburos.

En este estudio, mido el impacto de 13 ZA de la Amazonía Peruana (Tabla 3, Figura 2) sobre la deforestación y la propagación de concesiones mineras. Uso información de Hansen et al (2013) para la deforestación entre 2007 y 2012 y las concesiones mineras tituladas que fueron otorgadas después de 2007. Para establecer una estimación imparcial del impacto, uso el método estadístico de matching para controlar los factores relacionados con la deforestación o colocación de concesiones (por ejemplo, distancia a carreteras y depósitos de oro). Además de este análisis cuantitativo, conduje entrevistas en Lima y Puerto
Maldonado desde junio hasta agosto 2014. Uso la ZA de la Reserva Nacional Tambopata como un caso de estudio, para demostrar las limitaciones de las ZA para responder a amenazas ilegales.

6.2 Análisis cuantitativo

Los resultados del análisis cuantitativo muestran que las ZA en la Amazonía Peruana reducen el establecimiento de nuevas concesiones mineras y, en algunos casos, la deforestación. Para la deforestación, cinco de las 13 ZA redujeron la deforestación: Ashaninka/Otishi/Machiguenga, Yanachaga Chemillen, Tabaconas Namballe, Río Abiseo, y Yanesha/ San Matias San Carlos (Figura 4). Todas estas ZA están ubicadas en la zona de transición entre los bosques de selva baja y los Andes, en donde la tasa de deforestación es más alta que en la selva baja. Encontré que hay menos concesiones mineras que lo previsto en 10 de las 13 ZA (Figura 7), con un impacto total de -2.90%. Estas 13 ZA redujeron el área en concesiones mineras por 1739 km² que lo previsto alrededor de las ANP (Figura 8).

El impacto congruente en concesiones mineras pero no en deforestación refleja la claridad de la legislación. El SERNANP tiene la jurisdicción de controlar las concesiones directamente, pero no tiene el poder para fiscalizar las actividades que deforestan sin permiso. Además, una meta central de la legislación es controlar las actividades extractivas que puedan dañar las ANP, no la deforestación. Como veremos en el caso de Tambopata, las ZA no tienen mucho poder contra las amenazas ilegales.
6.3 Estudio de caso: Reserva Nacional Tambopata

La principal amenaza ambiental en la región de Madre de Dios es la minería de oro ilegal. Esta minería ha deforestado más de 50.000 km² de bosque desde 1999 y contaminado el agua con mercurio. Un sitio de minería fuerte, La Pampa, está dentro de la ZA. Esta situación entonces representa una prueba para las ZA contra las actividades extractivas ilegales. Como varias de las ZA consideradas en este estudio, la ZA de Tambopata ha reducido el número de concesiones mineras, pero no tiene impacto en la deforestación.

Durante agosto de 2014, fui a Puerto Maldonado para entrevistar personas involucradas en el manejo de esta ZA, para aprender más sobre los problemas de manejo, la respuesta al boom de oro, y sobre posibles sugerencias para mejorar la ZA.

En general, mis informantes opinaban que la ZA no ha tenido ningún impacto sobre la minería ilegal en La Pampa. Una gran parte del problema es la ambigüedad de responsabilidades en la ZA. SERNANP tiene el poder de hacer decisiones vinculantes sobre las actividades dentro de las ZA, pero es menos claro quién tiene la responsabilidad de supervisar y fiscalizar. Según un empleado de MINAM, las agencias regionales tienen esta responsabilidad dentro de sus concesiones, pero el informante teme que estas agencias no saben acerca de estas responsabilidades. Al contrario, todos los miembros de las agencias regionales (DRFFS, DREMH, DRA) con quienes hablé sabían sus responsabilidades, pero no tenían los recursos, financieros o personal, para cumplir. El DRFFS estaba sancionado por el gobierno central por hacer una brecha de autoridad cuando ellos trataban de monitorizar en la ZA. Una agencia que está haciendo su función en la ZA es OSINFOR, que hace monitoreo en las concesiones forestales. El sitio minero de La Pampa traslapa con docenas de concesiones de reforestación; 20 de los concesionarios han sido multados, y 4 de las
concesiones han sido canceladas. Pero aún cuando hay monitoreo, no significa que los mineros mismos están siendo sancionados. La minería ilegal ahora es criminal, pero hasta el momento, sólo tres mineros han entrado a la cárcel, y todos salieron temprano. También, la fiscalización sólo ocurre a través de la fiscalía. En Madre de Dios, sólo hay dos fiscales ambientales, y uno viaja a Cusco al tribunal por la mitad de la semana.

Las interdicciones del estado nacional tampoco han parado la minería ilegal en la ZA o afuera. Mis informantes me decían que estas interdicciones nunca son una sorpresa para los mineros porque de alguna forma, reciben la información antes de cada ataque en alguna . Aparte de las interdicciones, no hay mucha presencia del estado en estas zonas.

Aunque las actividades del estado nacional y regional no están haciendo nada para controlar la minería ilegal en la ZA de Tambopata, hay alguna esperanza en los grupos comunales. El comité de gestión de Tambopata es uno de los más activos en todo Perú, y está haciendo un gran esfuerzo contra minería y otras actividades ilegales en la ZA. Su proyecto más notable en la ZA es la capacitación de la gente local para reportar infracciones ambientales y publicarlas en www.alertaambiental.pe con el fin de sacar una reacción rápida.

Obviamente, hay problemas con la ZA de Tambopata. Está funcionando para frenar la expansión de concesiones mineras, pero no tiene las herramientas necesarias para parar la minería ilegal dentro de sí. Mis informantes ofrecieron muchas sugerencias, incluyendo el control total de SERNANP en la ZA (SERNANP está parando minería ilegal dentro de la ANP), la formación de un Área de Conservación Privada, y la expansión del rol de comité de gestión. Pero la sugerencia más común eraclarificar las responsabilidades de cada agencia dentro de la ZA, y capacitarlas con presupuesto, conocimiento, y personal para cumplir sus responsabilidades.
6.4 Conclusiones

En general, las zonas de amortiguamiento en Perú sí tienen un impacto fuerte en la expansión de concesiones extractivas. Esto representa un éxito para la conservación, porque las actividades dañinas no están siendo ubicadas cerca de las ANP. También, no hay un impacto grande en el desarrollo económico, porque estas actividades simplemente se mueven a otras áreas. A pesar de la reorganización exitosa de actividades, las ZA no tienen capacidad para controlar actividades ilegales dentro de sus fronteras, como hemos visto en el caso de la ZA de Tambopata. Para mejorar las ZA y continuar conservando las ANP, se debe clarificar las responsabilidades de varias agencias y se debe capacitar al personal de las agencias para que estas responsabilidades se puedan cumplir.
7. References


Wells, M., Brandon, K., & Hannah, L. (1992). People and parks: Linking Protected Area Management with Local Communities. The World Bank, WWF, USAID. Washington, DC.

8. Figures and Tables

Figure 1: The SERNANP (National Service for Natural Protected Areas) approval process for extractive activities in Peruvian buffer zones. SERNANP is involved in the compatibility and OTPF (Favorable Technical Previous Opinion) stages.

Potential concessioner applies for a concession from the relevant agency

Agency requests approval from SERNANP

If approved, the concession is granted, but extraction requires an Environmental Impact Statement

Concessioner submits an Environmental Impact Statement to extract

SERNANP and other agencies can approve or impose conditions

If approved by all agencies, the concession is granted

Compatibility

OPTF

1The relevant agency depends on the type and scale of the concession. For example, large scale mining concessions are granted by the Ministry of Energy and Mining (MINEM), while smaller concessions are granted by the Regional Offices of Mining, Energy, and Hydrocarbon.

2Other agencies that may have to approve the Environmental Impact Statement include the agency that granted the concession, the National Water Authority (ANA), and other agencies with overlapping concessions (e.g. the Ministry of Agriculture if a mining concession overlaps an agricultural title)
Table 1: Covariates used for matching analyses to determine PA effectiveness in Latin America.

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Number of studies</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to forest edge</td>
<td>5</td>
<td>Andam et al, 2008; Nolte et al, 2013; Pfaff et al, 2009; Pfaff et al, 2014; Scullion et al, 2013</td>
</tr>
<tr>
<td>Travel time to cities</td>
<td>3</td>
<td>Blackman, 2014; Nelson &amp; Chomitz, 2011; Nolte et al, 2013</td>
</tr>
<tr>
<td>Ecoregion</td>
<td>2</td>
<td>Joppa &amp; Pfaff, 2011; Pfaff et al, 2009</td>
</tr>
<tr>
<td>Baseline forest cover</td>
<td>1</td>
<td>Nolte et al, 2013</td>
</tr>
<tr>
<td>Conflicting land use</td>
<td>1</td>
<td>Scullion et al, 2013</td>
</tr>
<tr>
<td>Distance to mill</td>
<td>1</td>
<td>Pfaff et al, 2009</td>
</tr>
<tr>
<td>Distance to rivers</td>
<td>1</td>
<td>Scullion et al, 2013</td>
</tr>
<tr>
<td>Distance to school</td>
<td>1</td>
<td>Pfaff et al, 2009</td>
</tr>
<tr>
<td>Population</td>
<td>1</td>
<td>Blackman, 2014</td>
</tr>
<tr>
<td>Probability of flooding</td>
<td>1</td>
<td>Nolte et al, 2013</td>
</tr>
<tr>
<td>Temperature</td>
<td>1</td>
<td>Blackman, 2014</td>
</tr>
</tbody>
</table>
Table 2: Matching techniques used by various studies to determine PA effectiveness in Latin America.

<table>
<thead>
<tr>
<th>Study</th>
<th>Matching method</th>
<th>Other notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andam et al, 2008</td>
<td>Covariate</td>
<td>Used two nearest neighbors and averaged their values, experimented with and without 0.5 SD caliper, also tried genetic matching and found little difference</td>
</tr>
<tr>
<td>Pfaff et al, 2009</td>
<td>Propensity score</td>
<td>Matched four nearest neighbors to treated pixels</td>
</tr>
<tr>
<td>Joppa &amp; Pfaff, 2011</td>
<td>Covariate</td>
<td>None</td>
</tr>
<tr>
<td>Nelson &amp; Chomitz, 2011</td>
<td>Covariate</td>
<td>With and without 0.5 SD caliper</td>
</tr>
<tr>
<td>Nolte et al, 2013</td>
<td>Unspecified</td>
<td>With 1 SD caliper, used matching to form a control group, then used a regression instead of a difference-in-means test</td>
</tr>
<tr>
<td>Pfaff et al, 2014</td>
<td>Propensity score</td>
<td>Tested different numbers of matches for each treated observations</td>
</tr>
<tr>
<td>Scullion et al, 2014</td>
<td>Genetic matching</td>
<td>None</td>
</tr>
<tr>
<td>Blackman, 2014</td>
<td>Covariate</td>
<td>With and without 1 SD caliper</td>
</tr>
</tbody>
</table>
**Table 3:** Buffer zones in the Peruvian Amazon used in this study (a backslash separates PAs that share the same buffer zone).

<table>
<thead>
<tr>
<th>Name</th>
<th>Code</th>
<th>PA year created</th>
<th>BZ year created</th>
<th>PA IUCN category</th>
<th>PA Area (km²)</th>
<th>BZ Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuntanain</td>
<td>TU</td>
<td>2007</td>
<td>2007</td>
<td>VI</td>
<td>949</td>
<td>2948</td>
</tr>
<tr>
<td>Ichigkat Muja</td>
<td>IM</td>
<td>2007</td>
<td>2007</td>
<td>II</td>
<td>884</td>
<td>1421</td>
</tr>
<tr>
<td>Allpahuayo Mishana</td>
<td>AM</td>
<td>2004</td>
<td>2007</td>
<td>VI</td>
<td>580</td>
<td>663</td>
</tr>
<tr>
<td>Santiago Comaina</td>
<td>SC</td>
<td>1999</td>
<td>2007</td>
<td>none</td>
<td>3984</td>
<td>2025</td>
</tr>
<tr>
<td>Rio Abiseo</td>
<td>RA</td>
<td>1983</td>
<td>2006</td>
<td>II</td>
<td>2745</td>
<td>6853</td>
</tr>
<tr>
<td>Yanachaga-Chemillen</td>
<td>YC</td>
<td>1986</td>
<td>2005</td>
<td>II</td>
<td>1220</td>
<td>644</td>
</tr>
<tr>
<td>Yanesha/ San Matias San Carlos</td>
<td>YS</td>
<td>1988/ 1987</td>
<td>2001</td>
<td>VI</td>
<td>374/ 1458</td>
<td>2241</td>
</tr>
<tr>
<td>Ashaninka/ Otishi/ Machiguenga</td>
<td>AO</td>
<td>2003/ 03/ 04</td>
<td>2007</td>
<td>VI / II / VI</td>
<td>1844 / 3059/ 2189</td>
<td>9872</td>
</tr>
<tr>
<td>del Manu</td>
<td>MN</td>
<td>1973</td>
<td>2001</td>
<td>II</td>
<td>17162</td>
<td>13255</td>
</tr>
<tr>
<td>Alto Purus</td>
<td>AP</td>
<td>2004</td>
<td>2007</td>
<td>II</td>
<td>25106</td>
<td>14736</td>
</tr>
<tr>
<td>Purus</td>
<td>PU</td>
<td>2004</td>
<td>2007</td>
<td>VI</td>
<td>2020</td>
<td>2032</td>
</tr>
<tr>
<td>Tambopata/ Bahuaja Sonene</td>
<td>TB</td>
<td>2000/ 1996</td>
<td>2005</td>
<td>VI / II</td>
<td>2747 / 10914</td>
<td>4500</td>
</tr>
</tbody>
</table>
Figure 2: Map of the 13 buffer zones that are studied in this paper (buffer zone codes can be found in Table 1).
Table 4: List of layers and sources

<table>
<thead>
<tr>
<th>Name</th>
<th>Year(s)</th>
<th>Source</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protected areas</td>
<td>Through Feb 2013</td>
<td>SERNANP</td>
<td></td>
</tr>
<tr>
<td>Buffer zones</td>
<td>Through 2012</td>
<td>SERNANP</td>
<td></td>
</tr>
<tr>
<td>Deforestation</td>
<td>2000-2012</td>
<td>Hansen et al, 2013</td>
<td>I use the “Loss Year” layer for matching, and the “2000 Forest Cover” layer for determining the distance to forest edge</td>
</tr>
<tr>
<td>Population centers</td>
<td>2007</td>
<td>INEI</td>
<td>I use population centers with more than 50,000 inhabitants</td>
</tr>
<tr>
<td>Rivers</td>
<td>2003</td>
<td>IGN</td>
<td>I use second level hydro data</td>
</tr>
<tr>
<td>Roads</td>
<td>2005</td>
<td>MTC</td>
<td>I use all national and regional roads that are not “trochas”</td>
</tr>
<tr>
<td>Agricultural suitability</td>
<td>2002</td>
<td>Fischer et al, 2002</td>
<td>I use plate 28, ranked from 0 – no constraints to agriculture to 9 – severe constraints</td>
</tr>
<tr>
<td>Slope</td>
<td>2000</td>
<td>SRTM NASA</td>
<td>Derived from elevation layer</td>
</tr>
<tr>
<td>Elevation</td>
<td>2000</td>
<td>SRTM NASA</td>
<td></td>
</tr>
<tr>
<td>Department</td>
<td>2007</td>
<td>INEI</td>
<td></td>
</tr>
<tr>
<td>Mineral deposits</td>
<td>2014</td>
<td>INGEMMET</td>
<td>Includes placer gold deposits</td>
</tr>
<tr>
<td>Mining concessions</td>
<td>Through 2012</td>
<td>INGEMMET</td>
<td>I use only titled concessions</td>
</tr>
<tr>
<td>Petroleum concessions</td>
<td>Through Jan 2014</td>
<td>PeruPetro</td>
<td>Freely available online from the PeruPetro website</td>
</tr>
<tr>
<td>Conservation concessions</td>
<td>Through 2011</td>
<td>OSINFOR</td>
<td></td>
</tr>
<tr>
<td>Ecotourism concessions</td>
<td>Through 2011</td>
<td>OSINFOR</td>
<td></td>
</tr>
<tr>
<td>Reforestation concessions</td>
<td>Through 2006</td>
<td>OSINFOR</td>
<td>No new reforestation concessions were granted after 2006</td>
</tr>
</tbody>
</table>

Table 5: List of interviews.

<table>
<thead>
<tr>
<th>Code</th>
<th>Date</th>
<th>Professional Affiliation</th>
<th>Type of organization</th>
<th>Interview Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-L-NG1</td>
<td>7/2/14</td>
<td>Peruvian Society for Environmental Law (SPDA)</td>
<td>Environmental Law NGO</td>
<td>Lima</td>
</tr>
<tr>
<td>I-L-NG2</td>
<td>7/7/14</td>
<td>Wildlife Conservation Society-Peru</td>
<td>International Conservation NGO</td>
<td>Lima</td>
</tr>
<tr>
<td>Code</td>
<td>Date</td>
<td>Organization</td>
<td>Type</td>
<td>Location</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>I-L-G3</td>
<td>7/8/14</td>
<td>National Service of Natural Protected Areas (SERNANP)*</td>
<td>Government environmental agency</td>
<td>Lima</td>
</tr>
<tr>
<td>I-L-G4</td>
<td>7/10/14</td>
<td>Programa Bosques</td>
<td>Government forest management agency</td>
<td>Lima</td>
</tr>
<tr>
<td>I-L-NG5</td>
<td>7/21/14</td>
<td>Conservation International –Peru</td>
<td>International Conservation NGO</td>
<td>Lima</td>
</tr>
<tr>
<td>I-L-G6</td>
<td>7/21/14</td>
<td>(withheld)*</td>
<td>Government extraction agency</td>
<td>Lima</td>
</tr>
<tr>
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**Figure 3**: Deforestation rates from 2007 to 2012 observed in protected areas, buffer zones, the 10km surrounding area, and the difference between the surrounding area and buffer.

**Table 6**: Covariate match balance for pooled buffer zone analysis. Agricultural suitability is ranked from 1 (no constraints to agriculture) to 9 (severe constraints).

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Status</th>
<th>Buffer zone plots mean</th>
<th>Control plots mean</th>
<th>Standard mean diff.</th>
<th>Mean eQQ difference</th>
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**Figure 4:** Average treatment effect on the treated (ATT) for deforestation 2007-2012 using covariate matching. Significance is denoted by * for p < 0.05, ** for p < 0.01, *** for p < 0.001.

![Graph showing impact on deforestation (% of buffer zone area).](image)

**Figure 5:** Area of deforestation avoided in each buffer zone based on matching analysis (in km²).

![Bar chart showing deforestation avoided by buffer zone.](image)
Figure 6: Percent coverage of new mining concessions (2007-2013) in buffer zones, the 10km surrounding area, and the difference between the two.

Table 7: Covariate match balance for pooled buffer zone analysis for mining. Agricultural suitability is ranked from 1 (no constraints to agriculture) to 9 (severe constraints).

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Status</th>
<th>Buffer zone plots mean</th>
<th>Control plots mean</th>
<th>Standard mean diff.</th>
<th>Mean eQQ difference</th>
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</table>
**Figure 7:** Average treatment effect on the treated (ATT) for new mining concession area 2007-2013 using covariate matching. Significance is denoted by * for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$.

**Figure 8:** Area of mining concessions avoided in each buffer zone based on matching analysis (in km$^2$).
Figure 9: Map of the buffer zone of the Tambopata National Reserve.

Figure 10: Forest loss in the mining area known as La Pampa.
**Figure 11:** Average treatment effect on the treated for different concession types in the Tambopata buffer zone. Significance is denoted by * for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$. 

- **Mining**: Impact on concessions (% of buffer area) is approximately -20%.
- **Petroleum**: Impact on concessions (% of buffer area) is approximately -10%.
- **Conservation**: Impact on concessions (% of buffer area) is approximately 0%.
- **Ecotourism**: Impact on concessions (% of buffer area) is approximately 10%.
- **Reforestation**: Impact on concessions (% of buffer area) is approximately 20%.

Significance levels are indicated as follows:
- *: $p < 0.05$
- **: $p < 0.01$
- ***: $p < 0.001$
9. Appendix

9.1 Questions for participants in Lima

(Questions marked with an * were asked to all participants, others were asked depending on the expertise of the participants. All interviews were conducted in Spanish.)

*Why were buffer zones created?
Who decided that buffer zones should be implemented in Peru? Were any outside organizations involved in creating this legislation?

*What are the 3 biggest threats to Protected Areas in the Peruvian Amazon? How have buffers played a role in combating these threats?

*Why are buffer zones necessary in Peru? Are there any drawbacks to having buffer zones?
Who drew the buffer zone boundaries? Were buffers drawn by INRENA in Lima, or did each PA decide on its own buffer zone boundaries? How were the boundaries decided? If buffers are drawn individually, is there a specific case that you are familiar with?

Why isn’t there a budget for buffer zone management?

*From what I have read in the legislation, it appears that the only authority anyone has over buffer zones is SERNANP’s ability to approve or deny Environmental Impact Statements. Who is in charge of deciding which Environmental Impact Statements are approved and which are denied? Are there specific criteria on which these are judged?

*Which activities must file an Environmental Impact Statement for extraction in the buffer zone?
Are these decisions archived? If so, would I be able to see some examples?

Is there any tension between SERNANP and other branches of the government (like MINEM) about what is allowed in the buffer zone? Have there been any conflicts over buffer zone use, and what have they been about? How have they been resolved?

Who is responsible for promoting ecotourism, reforestation, agroforestry, and other sustainable activities in the buffer zone? How do they go about promoting these activities?

*Where is there room for improvement in buffer zone policy or management?
*Have you heard of any specific cases of buffer zones that are working especially well? … that are not working?

*Below are the preliminary results for a deforestation study I am conducting within buffer zones… It appears that some buffers are reducing deforestation compared to the outside area, while others are not. Does anything surprise you? Why do you think some buffer zones are working better than others?

9.2 Questions for participants in Puerto Maldonado

What are the 3 biggest threats to the Tambopata National Reserve? Has the buffer zone had a role in combatting these threats?

Why are buffer zones necessary in Peru? Are there drawbacks of having buffer zones?

What is the ecological and social role of buffer zones? How do the buffer zones affect the people who live inside of them?

Who drew the boundaries of the buffer zone? How did they decide where to draw them?

What happens when a person or Company tries to obtain a concession inside the buffer zone? How does this differ for different types of concessions? What types of concessions need to obtain approval?
What does a person or company have to do to get approval from SERNANP? Who do they send the application to? How long does it take?

Do you know of a specific case of concessions that were approved or denied by SERNANP in the buffer zone? Do you think the process of approval is working?

Are buffer zones slowing damaging activities inside of their boundaries? How are park guards, SERNANP, and other NGOs responding to illegal mining activities inside the buffer zone?

What are the functions of different groups in the management of the buffer zone? What does the Management Committee do?

Do you believe that the buffer zone of the Tambopata National Reserve is working to reduce threats to the reserve? Why?

How could legislation and management be improved?