Crossing the Line on Governance: Evaluating the Impact of National and Transboundary Protected Areas on Land Cover Outcomes in Central America

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Abstract

Understanding the relationship between transboundary conservation designation and effectiveness is fundamental to assess the theoretical assumptions around how drivers of land cover and land use change (LCLUC) affect these conservation approaches at regional and sub-regional scales. This dissertation explores opportunities and challenges of national and transboundary protected areas (PAs) within a transboundary region. This work focuses on PAs created between 1986 and 2016 in the Trifinio Region, Central America, which spans Guatemala, Honduras and El Salvador. There are three chapters. The first chapter uses mixed methods to explore how key elements of governance processes related to decentralization in decision-making, management capacity, and management category contribute to achieving conservation objectives of PAs. Chapter two presents a rigorous evaluation of the impact of PA governance on LCLUC outcomes using remote sensing and econometric analysis. It examines how impact changes across 15 PAs by level of restriction, levels of decentralization, and management capacity. The last chapter analyzes the impact of transboundary protection on LCLUC outcomes by comparing PAs across countries in Trifinio and by comparing PAs inside the transboundary area to those just outside Trifinio. This dissertation highlights the complex relationship between governance components such as decentralization, management capacity, and management restrictions and informs local conservation policy about how governance affects PA outcomes on the ground. In addition, this work sheds light on drivers of change operating within and across countries and contributes to the theory on cross-country and transboundary PA effectiveness and rigorous impact evaluation of PAs.

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Dedication

To my wife, Shirley Murillo Ulate,

for her companionship, unlimited support, and for being a true friend.

To our son Héctor Emilio,

whose generation will face the new challenge of nature conservation.

A mi querida madre Alicia Muñoz,

quien es una de las mujeres más fuertes y tenaces que conozco.

(To my dear mother Alicia Muñoz,

who is one of the strongest and tenacious women I know).

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Introduction

Despite global recognition of the importance of biodiversity and the benefits to societies from ecosystem services (ES) provided from forest lands, worldwide deforestation continues at a disturbingly high rate. According to FAO's Global Forest Resources Assessments, at the global level nearly 13 million hectares were deforested per year in the last decade compared with 16 million hectares per year in the 1990s (FAO, 2006, 2010). For North and Central America the area of forest loss was almost the same in 2010 as in 2000. However compared to North America and the Caribbean sub-regions, all Central American countries (except Costa Rica) experienced the highest annual reduction in forest area between 1990 and 2000 of 1.56%, or 374,000 ha per year, and of 1.19% between 2000 and 2010, or 248,000 ha per year (FAO, 2010, pp. 18-19).

Protected areas (PAs) are a prominent conservation approach used throughout the world and in Central America (CA) to minimize the degradation of natural resources from land use change. Conducting rigorous studies to measure how protection reduced deforestation are important to assess these effects. For example, Andam, Ferraro, Pfaff, Sanchez-Azofeifa, and Robalino (2008) used matching methods for evaluation and found that approximately 10% of forests in PAs would have been cleared without protection. Ferraro and Hanauer (2011) found that PAs help alleviate poverty by provisioning ES, coupling tourism with conservation, and with infrastructure development.

Human decisions about natural resource management and governance directly impact natural systems and the provision of ES. These changes have direct consequences for human systems revealed in the ways ES impact our well-being, livelihoods, our capacity for sustainable development and resilience. The effects from the human systems on the ecological systems are best described in the ways the ecosystems are able to support life, functions, and their resilience (Folke, Hahn, Olsson, & Norberg, 2005; Ostrom, 2009). These interdependencies and feedbacks are of particular importance in developing countries which have high rates of poverty and biodiversity, making these places highly vulnerable to shocks in the natural or social systems (IPCC, 2014). For example, ES loss threatens the natural capital that enables development opportunities in tropical countries, especially for the poor (Millennium Ecosystem Assessment, 2003).

The purpose of this dissertation is to analyze the impact of national and transboundary PAs on LCLUC in Trifinio, Central America. This was done by integrating remote sensing, spatial econometrics, and interviews to explore the relationships between protection and governance aimed at reducing LCLUC outcomes. In Chapter 1, I explore the central issue of how governance processes (decentralization, capacity, and management category) in state PAs are related to their ability to maintain biodiversity, cope with challenges, and prevent land use change. Qualitative data—including two Likert scales that measured the level of PA decentralization in decision-making and management capacity—and quantitative data were collected through interviews with key informants and use to create indices of decentralization and management capacity. The International Union for Conservation of Nature (IUCN) classification system of PAs was used to create a restriction index. Cluster analysis was used to group and compare 16 PAs by restriction categories, decentralization, and capacity. This chapter contributes to understanding the complexity between elements of PA governance and conservation outcomes.

Chapter 2, I conduct a rigorous evaluation of the impact of PA governance on land cover outcomes in the Trifinio Region between 1986 and 2016. The central question is whether and how different governance mechanisms help PAs prevent LCLUC outcomes. This evaluation assessed the impact all 15 forest PAs in Trifinio. It compares the impact from PAs by levels of restriction, decentralization, and capacity. The outcome variable is Normalized Difference Vegetation Index (NDVI) measured at the pixel level over seven epochs. Propensity Score Matching and selected biophysical and socioeconomic covariates were used to estimate the average treatment effect on PA pixels for the different governance classifications. This chapter contributes broadly to land use and governance and LCLUC theory. The research findings are important to inform local conservation policy and advance theory about how governance affects PA outcomes in developing countries.

Chapter 3 focuses on the contributions from transboundary conservation to mitigate the impact from LCLUC. Conservation across borders is becoming an important arrangement for the protection and maintenance of biodiversity at spatial scales beyond political and administrative borders. This form of conservation fosters habitat connectivity and cooperation among the key actors involved, but there are no existing impact evaluations of transboundary areas on LCLUC. Transboundary PA effectiveness is assessed by estimating the impact of 15 PAs on changes in NDVI using quasi-experimental methods of matching. I compare PA outcomes across the three countries and compare PA impacts inside Trifinio to the impact of 11 PAs just outside Trifinio but in the same countries. This chapter advances theory on cross-country and transboundary PA effectiveness and rigorous impact evaluation of conservation interventions at regional and sub-regional scales.

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Chapter 1 Governance Processes of Protected Areas in Central America: A Framework for Analyzing Decentralization, Capacity, and Management Category

Abstract

Despite the relative prominence of PAs as a conservation strategy, evidence on how PAs achieve conservation outcomes remains mixed, and our theoretical understanding about what factors contribute to achieving PA management objectives is weak. PA governance is widely acknowledged as one critical factor for effective conservation. A central question in evaluating PA effectiveness is thus, how do different governance structures (e.g., centralized versus decentralized decision-making and management) affect the ability of PAs to prevent land use change and why. This study draws on qualitative interviews and the International Union for Conservation of Nature (IUCN) categories reported in the World Database on Protected Areas to create a governance index that characterizes 16 PAs by restriction categories, decentralization, and capacity in the Trifinio Region, Central America. We used cluster analysis to group PAs by their degree of decentralization and management capacity; we also grouped PAs by strict or multiple-use management categories. We find a complex and non-linear relationship between the governance components of decentralization, capacity, and restrictions. We found a strong relationship between high capacity and restrictive use management. The relationship between management restriction and decentralization is more complex but when decentralization policy exists at the country level, strict management can be associated with more decentralization and this association may affect management capacity in a positive way. The mechanisms that helped reduce threats and challenges and improve management outcomes the most were high capacity and high decentralization. Our findings suggest that using IUCN categories as proxy for governance does not fully embrace the complexities of PA governance and conservation outcomes. More in-depth and mixed methods studies are needed in other parts of the world to fully articulate all the potential pathways between governance and PA outcomes. This study provides important insight into the linkages between restriction, capacity, and decentralized governance in Central America.

Introduction

Protected areas (PAs) are a prominent conservation approach throughout the world. Approximately 13% of the earth's terrestrial surface and 3.4% of the global ocean area have been designated as some form of PA (Coad et al., 2010; Jenkins & Joppa, 2009), with the goal of safeguarding biodiversity, conserving ecosystems, sustaining ecological processes, and enhancing ecosystem services. The International Union for Conservation of Nature (IUCN) has created a widely used system for standardization of national PA categories which classify PAs according to their management objectives (Dudley, 2008). PAs have a wide range of management objectives, from highly protected sites with restrictions on access and use, to areas with fewer restrictions focused on multiple permitted uses of natural resources (Dudley, Stolton, & Shadie, 2013).

Despite the relative prominence of PAs as a conservation strategy, evidence of the impacts of PAs on achieving conservation outcomes remains mixed, and our theoretical understanding about what factors contribute to effectiveness of PAs is weak (Ferraro & Hanauer, 2015). PA governance is widely acknowledged as one critical factor for effective conservation and is a key feature in the Convention on Biological Diversity's (CBD) work program on PAs (Dearden, Bennett, & Johnston, 2005). PA governance structures are diverse—the IUCN and the CBD suggest a classification according to the key actors holding authority and responsibility for the main management decisions affecting PA creation, management type and administration (Borrini-Feyerabend et al., 2013). Knowledge on how PA governance affects conservation outcomes, however, is missing (Macura, Secco, & Pullin, 2013, 2015). A few studies suggest that deforestation outcomes of PAs are affected by their location and the governance regime effectiveness, which in turn are affected by the level of deforestation pressures, the intensity of government enforcement, and land use regulations. Findings from these studies are mixed. All types of PAs in the Brazilian Amazon helped reduce deforestation regardless of the management objectives, but strict PAs consistently avoided more deforestation than sustainable use areas, furthermore indigenous lands were effective in locations with high deforestation pressure (Nolte, Agrawal, Silvius, & Soares-Filho, 2013). PAs in Mexico can reduce or exacerbate deforestation within and outside their borders depending on geographic location (Blackman, Pfaff, & Robalino, 2015).

While many previous assessments of PA impacts measure governance with IUCN management category, it is not clear that a designation of strict versus multiple-use necessarily indicates strong governance processes or management capacity. More explicitly incorporating these governance elements into the study of the relationship between PA governance and outcomes is instrumental for theory development to understand the role of governance in PA outcomes, especially for regions where decision-making processes are shifting between centralized structures and collective action structures. Besides forest or land cover change indicators of environmental integrity and biodiversity status, other indicators related to governance are needed for assessing conservation outcomes of PAs (Porter-Bolland et al., 2012). In addition to measuring effectiveness in terms of avoided deforestation inside PAs, Gaveau et al. (2012) stress that if land use regulations governing unprotected lands used as controls are not considered, protection impact of PAs may be overestimated. It is clear that focusing on deforestation alone disguises ways in which PAs' multiple conservation goals are achieved and the lack of understanding of how PA governance matters to conservation outcomes makes it difficult to improve and design effective governance structures (Ferraro & Hanauer, 2015).

A key consideration in the study of PA governance is decentralization. Decentralization of natural resources implies increased involvement in decision-making and active participation in management by local-scale governments and non-state actors (Larson, 2003; Nygren, 2005). Often, it is also assumed that more local engagement leads to better outcomes in resource management because there is more acceptance for decisions informed by local knowledge (Gibson, McKean, & Ostrom, 2000). National legislation, policies, strategies, and plans define how decentralization processes may or may not be applicable to PAs within a country. These national institutions are often encouraged and guided towards decentralization by international actors such as the CBD, IUCN, and large NGOs. Dearden et al. (2005) found that over the past decade there has been an increase in decentralized and co-managed PAs governance structures, mainly driven by new legislation and policy and the influence of global forces. Starting in the early 1980s, decentralization reemerged as a valued political and economic strategy for development in most developing countries (Agrawal & Gupta, 2005).

Its promoters saw increasing efficiency gains as well as greater participation and engagement between government and citizens. Proponents of these ideas see decentralization as an opportunity for greater local participation and control in the governance process (Larson, Pacheco, Toni, & Vallejo, 2007; Larson & Soto, 2008) and suggest that highly centralized structures are less effective in achieving a policy goal compared to a decentralized one.

Others, however, have pointed to potential drawbacks, including cases where decentralization efforts do not increase the powers of local authorities or peoples (Agrawal & Ribot, 1999), or where greater participation does not necessarily lead to better conservation outcomes, for example, locals devise rules that allow forest conversion or greater access to resources and benefits in detriment to resource sustainability (Agrawal & Gupta, 2005; Faguet, 2014; Fuhr, 2011; Larson et al., 2007; Tacconi, 2007). This is in part because central government agencies may show resistance and limit transferring real powers to other entities (Larson & Soto, 2008; Ribot, Agrawal, & Larson, 2006). Another issue is whether lower levels of government and non-state actors have the management capacity or institutional oversight to carry out these decision-making processes. Management capacity is about having the means to accomplish management objectives as well as the right and ability to make effective decisions (Larson & Soto, 2008). Studies that explore the link between decentralization and forest management suggest that decentralization processes are limited by national historical context (e.g., past land uses, international investments on agriculture, institutional reforms, regulations, low government capacity), that inhibit decentralization of decision-making power over forests to local actors, but that forest management outcomes improve with increases in capacity, incentives, and commitment.

Central America (CA) is a hotspot for biodiversity and home to 12% of the world’s known species. Creating terrestrial PAs in CA has always been a challenge due to forest fragmentation, political instability, and high costs of natural resource protection (Holland, 2012). While the region is of high conservation value for its biodiversity, it is experiencing high rates of human population growth, ecosystem degradation, and loss of traditional farming practices (Harvey et al., 2008). Throughout the 1960s and 1970s, CA experienced one of the highest rates of deforestation in the world (FAO, 2010, pp. 18-19). Since 1960, the extent of forest cover in the region declined from approximately 60% to a third of the total land area. By 1990 the region was losing about a third of a million hectares of forest a year, but deforestation declined during this decade (Utting, 1997). Despite conservation challenges in CA, there are 670 PAs protecting nearly 12.4 million ha (roughly 24% of land area)—national parks and reserves increased from 30 in 1970 to more than 300 in 1987, covering about one sixth of the total land area (Utting, 1994). CA governments, international agencies, and national NGOs implemented policies, programs, and projects to conserve forests and encourage reforestation (Utting, 1991). For example, the Mesoamerican Biological Corridor (MBC), a regional initiative by the seven CA countries and five southern states of Mexico that covers 76, 9 million ha, is aimed at connecting many of the region's PAs and fragmented forests in the landscapes (IEG, 2012).

Although many PAs in CA are small, fragmented, isolated, or poorly protected (Holland, 2012; Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000) there is some evidence of their positive impact on conservation. Studies in Costa Rica indicate that PAs reduced deforestation by approximately 10% in areas that would have been deforested in the absence of PAs (Andam et al., 2008), and PAs closer to capital cities, closer to national roads, and on lower slopes had higher impacts on avoided deforestation. Other studies explored how key factors related to management restrictions influence deforestation outcomes and found that multiple-use PAs that are large, new, relatively well-funded, located near areas with high deforestation pressure show less deforestation compared to strict management that prohibits deforestation (Blackman et al., 2015; Pfaff, Robalino, Lima, Sandoval, & Herrera, 2013). Pfaff, Robalino, Sandoval, and Herrera (2015) found that highly restricted or multiple-use rules are related to PA location in low versus high deforestation pressure areas, size, and time of creation, which affect the impact on forest outcomes. Studies conducted in other regions (Nelson & Chomitz, 2011; Paul et al., 2013; Wendland, Baumann, Lewis, Sieber, & Radeloff, 2015) also use the level of management restriction determined by IUCN management categories as proxy for PA governance. However, these studies only explore rules for restriction in management in relation to outcomes but other elements of governance are missing.

In addition to management restriction, deforestation and reforestation outcomes are also related to decentralization and capacity in areas with higher population and road densities where the increased management capacity is the result from decentralization which contributes to achieving management goals due to increase in staff number working on reforestation (Paulson Priebe, Evans, Andersson, & Castellanos, 2015). These studies highlight that PA establishment, categorization, and impact is related to socio-political feasibility factors such as avoiding conflict that arise from land use restrictions. Thus, information to answer whether management categories are related or not to other governance factors pertaining to differences in decentralization of decision-making or management capacity is missing.

Given increasing interest in understanding how governance factors influence the ability of PAs to achieve their conservation and social outcomes (Macura et al. 2015), we analyzed the relationship between decentralization of decision-making, management capacity, and management category in order to develop a better conceptual understanding of the potential impact of governance on PA conservation goals. We conducted our analysis for 16 PAs in the transboundary region known as Trifinio, connecting parts of Guatemala, El Salvador, and Honduras. Trifinio is a political administrative transboundary area of 754,100 ha that resulted as an outcome of the 1987 Central American Peace Accords. This study area is interesting for analysis of PA governance because the region actively collaborates on conservation of Trifinio as a transboundary socio-ecological unit, while each country exhibits different social, economic, and political complexities that may influence governance processes.

We developed measures of these different elements of governance from key informant interviews and use clustering analysis to group PAs by their degree of decentralization and management capacity. We grouped PAs by strict or multiple-use management categories based on IUCN classification. We then analyzed how these factors are related to one another and how they are related to the threats and challenges linked to PAs conservation goals. Specifically, we explored if the level of decentralization and management capacity are related to one another and whether either of these factors is directly related to the IUCN management category. We also considered whether these governance factors affect the ways a PA responds to threats and challenges. Hockings (2003) prosed three broad categories of threats to PAs: (1) those affecting the natural and cultural resources; (2) inadequate resources for management; and (3) capacity problems, which include inappropriate policies and institutional arrangements, dysfunctional management systems, and inadequately trained staff. Thus, social and environmental threats, challenges, and pressures vary according to particular contextual settings, for example, the PA management category, size and location, ad administrative assets. Understanding how to best deal with challenges and threats of PAs is a central issue for decision makers.

Our assessment of the relationships between PA decentralization, capacity, and management category has broad implications. There are few conceptual frameworks for how governance structure and processes might affect PA outcomes (Agrawal & Gupta, 2005; Andersson & Gibson, 2007; Borrini-Feyerabend et al., 2013; Macura et al., 2015); in this paper we lay out the possible relationships between decentralization, capacity, management restriction, and PA outcomes that can be empirically tested in future studies. This helps elucidate how decentralization and capacity may relate to PA restriction and helps identify priorities for future research on PA governance to inform policy design. Specifically, for Trifinio, our analysis of governance informs current institutional strengthening efforts to improve management, administration, and connectivity of PAs in the Region.

Conceptual framework of governance and PAs

Governance has many definitions and can be difficult to operationalize. However, most definitions include elements of organization, regulation, processes, institutions, power, decision-making, and interactions and relationships among actors (Table 1.1). Governance is not government nor management—governance is the set of processes and institutions that help define management goals (Lautze, de Silva, Giordano, and Sanford (2011). Management is about implementing the practical measures to achieve those goals, its aim is to improve outcomes directly while governance seeks to define what good outcomes are and sets the decision-making process of management activities to achieve those goals.

Table 1.1. Common Definitions of Governance.

Stoker (1998)	Governance is about creating the conditions for ordered rule and collective action not by power or authority but by identifying the power dependence of institutions involved in collective action.
Lemos and Agrawal (2006)	Regulatory processes, mechanisms and organizations through which political and economic actors influence environmental actions and how their relationships shape identities, actions, and outcomes.
Schoon (2013)	Ordering relationships between people and groups of people through institutions.
Jessop (2003)	The reflexive self-organization of independent actors involved in complex relations of reciprocal interdependence, with such self-organization being based on continuing dialogue and resource-sharing to develop mutually beneficial joint projects and to manage the contradictions and dilemmas inevitably involved in such situations.
Larson and Soto (2008)	The formal and informal institutions through which authority and power are conceived and exercised and the political-administrative, economic, and social organization and accountability of power and authority.
Graham, Amos, and Plumptre (2003)	The interactions among structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken and how citizens or other stakeholders have their say.
Borrini-Feyerabend et al. (2013).	Governance is about who decides their objectives, how and with what means to pursue them; how decisions are taken; who holds power, authority and responsibility; and who is accountable.

Decentralized governance reflects a shift in decision-making from a centralized power authority to the incorporation of local state or non-state actors (Giessen & Buttoud, 2014). A pure model of decentralization is unlikely to be implemented in many countries given the existing institutional constraints present. The degree of centralization or decentralization is defined by the interactions between central authority and external actors involved in decision-making. The goals of decentralization of processes in forestry include reducing costs, increasing agency revenues, or better monitoring resource uses by local communities. An additional goal is to expand the work of the forest management agency into areas where its presence is weak (Larson & Soto, 2008). Decision-making for natural resources is embedded in power structures in which the level of control can be more or less decentralized between the state and non-state actors. The literature on governance of natural resources that focuses on decentralization has primarily concentrated on understanding the institutional arrangement and power relationships emerging from the process of decentralization or the implications from policy implementation justified on assumptions of gains in efficiency and equity from decentralization (Ribot, 2002; Ribot et al., 2006). While the focus of research has included forest management and the interactions between central authorities and local governments or on the relationship between local governments and other relevant local actors (Larson & Soto, 2008), there is little research on decentralization process in PAs, and how this affects their outcomes (Macura et al. 2015).

Capacity affects and is affected by decentralization. Providing the means to accomplish management objectives within an institutional framework to make effective decisions is what determines the level of management capacity (Larson & Soto, 2008). For example, findings by Bruner, Gullison, Rice, and da Fonseca (2001) suggest that management capacity—which is related to capacity of enforcement, boundary demarcation, and direct compensation to local communities—and conservation goals are correlated. Similarly, technical and financial capacity are key to managing resources well and affect the ability to promote governance processes to solve local environmental problems (Larson & Soto, 2008). Lack of capacity is consistently used by central authorities to limit decentralization and transfer of powers to local actors (Ribot, 2002); as Ribot points out this is "a chicken and egg problem" because lack of capacity limits decentralization but without decentralized power local actors cannot make decisions to gain capacity nor demonstrate their potential to gain it. As such, the analysis of decentralization and capacity must focus on the potential linkages and feedbacks that arise between these factors (Fiszbein, 1997).

PA governance structures vary according to the institutional embeddedness of the type of protection prescribed by national management categories that affects the level of restriction (e.g., strict, multi-use). The IUCN classification system consists of six management categories (i.e., Ia, Ib, II, II, IV, V, VI) from strictly protected where human visitation, use and impacts are controlled and limited as opposed to sustainable use areas where low-level non-industrial natural resource use is compatible with nature conservation (Dudley & Phillips, 2006; Dudley et al., 2013). PA management category is directly related to decentralization because national legislation determines whether a management category can be decentralized and the type of decentralization (e.g., devolution, deconcentration, delegation) defines the magnitude of participation by key actors—which is affected by the level of connection among actors across the PA governance structures from local-level to central government level, the degree of stakeholder engagement, community perceptions, and freedom from unwanted political influence in decision-making and management. This in turn is related to PA management capacity.

Decentralization Trilemma

The process of decentralization can have different characteristics depending on whether what is being decentralized is power for decision-making and authority or administrative responsibilities. Common pathways characterized in the literature include deconcentration, delegation, devolution, and privatization. For example, Larson and Soto (2008) and Puppim de Oliveira (2002) describe deconcentration, or administrative decentralization, as the transfer of powers and tasks by a central government agency to their regional offices located outside the capital. This is a form of regionalism of the geographical centers of power from the capital to local offices, but there are still dependencies on the authority of the central government for decision-making, budgets, and instructions. Delegation is for some scholars the transfer of responsibilities and powers to structures outside of government but still under governmental control (Ribot et al., 2006) and for others it excludes decision-making powers (Larson, 2003). Devolution has different meanings for different authors. For example, it may be the transfer of authority to community organizations (i.e. community-based natural resource management) as opposed to local governments which is closely related to democratic decentralization (Larson, 2003; Larson & Soto, 2008). It is also described as a complete transfer of decision-making regarding certain public responsibilities from a central government agency to lower level government institutions (Puppim de Oliveira, 2002). Privatization involves the provision of a service from a public to a private entity, but not all authors consider privatization to be a form of decentralization (Ribot et al., 2006). For Larson and Soto decentralization aims at expanding the public domain, whereas privatization decreases it. These conceptual distinctions take into account the participation aspect in the political process as well as the administrative component of decentralization.

Regardless of the type of decentralization or whether the issue is power or responsibility transfers, these processes must deal with what we call the “decentralization trilemma” of governance depicted in Figure 1.1. This trilemma reinforces the idea that a pure model of decentralization is unlikely to be implemented due to governance constraints. Governance processes of PAs, or natural resources in general, will determined where and how power or administrative decision-making are allocated in three polarities (shown in black boxes). The allocation can be at the central government, community group, or corporation levels, but their respective forms of operation—i.e., centralized, distributed, or privatized—make power and decision-making sharing incompatible among these poles. Governance structures (in blue round boxes) mainly define the management nature of the resource and set the direction for either public domain contraction or expansion shown in green dash-dotted lines; public domain expansion is maximized from left to right from a centralized form of operation to a distributed one. The key actors involved will set their preference for control of resources in any given structure based on contextual factors. The gold, purple, and red arrows point the flow of power or direction of decision-making responsibility characterized by policies of centralization, decentralization, privatization, municipalization, and communization. The latter two policies are increasing their relevance in the context of communist regimes and political transitions as local governments and communities become more empowered to manage their resources (Dickovick, 2007; Noys, 2012).

The “decentralization trilemma” exists because to change the allocation of power from one pole to another only two pathways are possible. By choosing one path for transfer, actors must forgo the third pathway and in consequence only one pure form of operation is attained. For example, the state can have absolute control over PAs with the aim of minimizing interference of any kind by non-state actors. This implies absolute concentration in decision-making by the government at a central level and may even imply nationalization of private resources (upward path in maroon). Power over PAs can be shared between the central government and its regional agencies, local governments, communities, or NGOs with the aim of democratizing control—this is decentralization characterized above as devolution, deconcentration delegation, and is highlighted with the rightward arrow in gold. Finally, PAs can be privatized by transferring their absolute control to corporations, NGOs or individuals with the aim of minimizing interventions from any type of government and other non-state actors (downward arrows in maroon and purple). Whereas decentralization is about more participation at regional and local levels of state and none-state actors—the path in the upper green dotted arrow—privatization leads to what we call hypercentralization of control by private actors; the path shown with the lower green dotted arrow. The governance trilemma of decentralization policy affects decision-making, participation in the political process, and management capacity which in turn affect PA management outcomes (Figure 1.1).

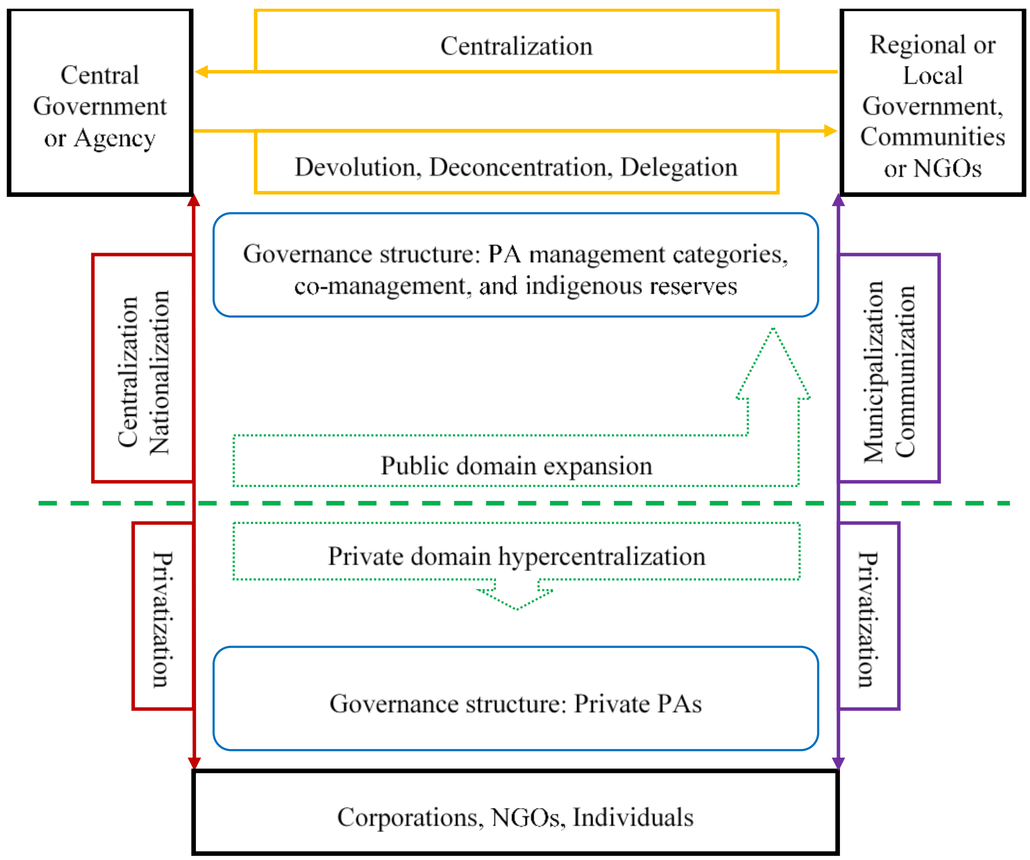

Figure 1.1. Decentralization trilemma of governance.
Power or administrative decision-making are allocated in three polar centers (black boxes) where the central government, community group, or corporation levels operate in centralized, distributed, or privatized forms making power and decision-making sharing incompatible among these poles. Governance structures (blue round boxes) define the management nature of the resource. Public domain expansion is maximized from left to right from a centralized form of operation to distributed one. The gold, purple, and red arrows point the flow of power or pathways of decision-making responsibility characterized by policies of centralization, decentralization, privatization, municipalization, and communization. Actors must decide between two paths for transfer and only one pure form of operation is attained. Transfer by decentralization from the State pole to regional and local levels leads to more participation and privatization leads to hypercentralization.

Causal relationships between PA governance and outcomes

The directed acyclic graph or DAG (Textor, Hardt, & Knüppel, 2011) in Figure 1.2 shows the hypothesized causal pathways of the effect of PA governance, by starting from the creation of PA as the intervention to protection outcomes. This is our assessment of casual connections between governance and outcomes based on the literature to date, but other variations might exist. In the causal path between the treatment and outcome are mechanisms (elements that help explain the relationship between the intervention and outcome; each treatment may operate through different mechanisms). Moderators are not on the causal path and are unaffected by the treatment but influence the magnitude of the treatment effect. Confounding variables affect treatment, mechanisms and outcomes and can mask, mimic or moderate the impacts of the treatment (Ferraro & Hanauer, 2015). The arrows show the direction and feedback loops that confound the relationships between variables when one factor affects one or more elements in the DAG. As explained above the interaction between decentralization and capacity is bidirectional. The form of decentralization can vary as described in Figure 1.1. Both the form of decentralization and the level of capacity are affected by the management category designation. Achieving higher levels of decentralization and capacity may be limited by resistance from relevant actors and lack of participation, which moderate the effect of PAs on outcomes (Figure 1.2). Thus, the causal pathway will be informed by understanding the legal and institutional structures that foster or constrain decentralization, taking into account relevant actors involved in decision-making, and controlling for the key confounding factors that also affect outcomes (Larson, 2003).

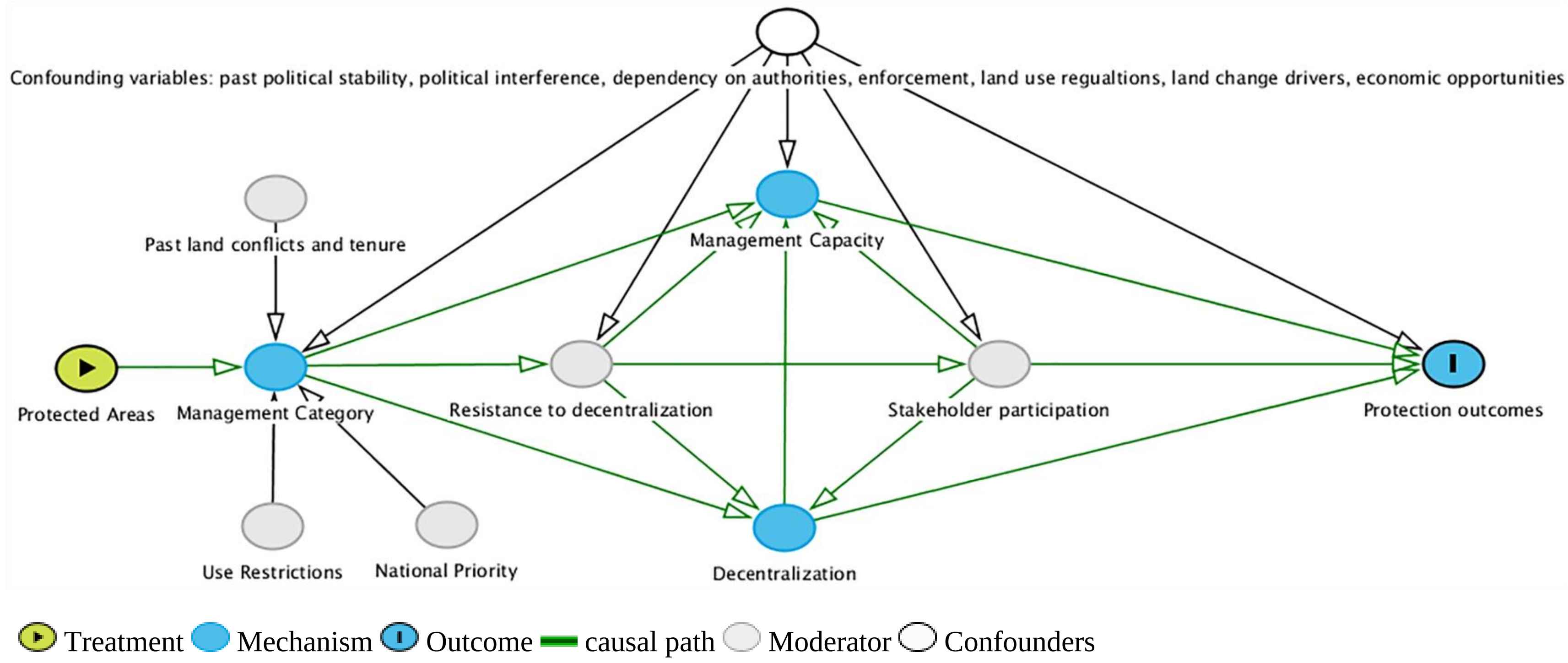

Figure 1.2. Directed Acyclic Graph (DAG) of PA governance structure.
Green arrows show the causal effect of PA (treatment green circle) on protection goals (outcome marked blue circle) through PA (1) management category, (2) decentralization, and (3) capacity (mechanisms blue circle). The treatment effect on the outcome can be assessed by measuring the changes in levels of these variables. Moderator variables (i) past land conflicts and land tenure, (ii) resource use restriction, (iii) resistance to decentralization, and (iv) stakeholder participation (all in gray) moderate the effect of PA creation by contributing to determine the political feasibility of assigning a management category, the levels of decentralization and capacity but do not affect PA creation. Confounding variables (white circle) affect treatment, mechanisms, and the outcomes and disguise PAs impacts.

When assessing the relationship between management category, decentralization processes, and capacity of PAs it is important to take into account contextual features related to historical, political, social, biophysical, and economic settings (Agrawal, Chhatre, & Hardin, 2008), which in turn help explain current conditions within the PA and in unprotected sites (i.e., deforestation spillovers or community displacement effects). Governance structures are shaped by these contextual factors—some of which may lay outside the causal path—that moderate the critical elements of governance which could help achieving positive outcomes.

Contextual features are also important in understanding why a particular PA was designed as a particular type of management category. When contextual forces lead to the establishment of PAs with a strict management category, it is expected that the degree of decentralization and stakeholder participation is lower. This implies that there are fewer actors involved in decision-making and management, with fewer responsibilities, and authority associated with a highly centralized structure. In turn, this type of governance structure affects the decentralization processes and management capacity that could potentially help improve LCLUC outcomes.

Having good knowledge of contextual features can help understand the origins of threats and challenges of a PA. Although the types of threats and challenges may be similar across PAs, the ways and capacity to confront them may be different depending on PA category, decentralization level, and management capacity, and this affects outcomes—it has been assumed that stricter rules and PAs under state control lead to better management outcomes as compared to flexibility in land uses in multiuse PAs under community management, but this approach ignores key aspects of social and political processes that affect conservation interventions in specific contexts (Wilshusen, Brechin, Fortwangler, & West, 2002).

Methods

Study area

The Trifinio Region (Figure 1.3) was created to promote the conservation and sustainable use of natural resources as well as the protection of their historical and cultural heritages. The decision to manage this region as “a indivisible ecological unit” is formally reflected with the creation of the Plan Trifinio Tri-National Commission (PTTC) in October 31, 1987 and its governance structure (OAS, 1993)[1]. In addition, these countries established in November 21, 1987 the Trifinio-Fraternidad International Reserve of the Biosphere (MARN, 2010). This reserve is composed of three PAs which have different names in the different countries— Montecristo National Park in El Salvador, Montecristo Trifinio National Park in Honduras, and Trifinio National Park and Biosphere Reserve in Guatemala. The reserve includes a large area of cloud forest within its core PAs that surround the Montecristo massif, a buffer zone, and an area of multiple-use for the land. In 2011 the reserve became part of the UNESCO-MAB system and the first tri-national biosphere reserve in Central America with an area of 22,100 ha and is considered an example of international cooperation for environmental protection and local sustainable development. (UNESCO, 2011). This transboundary PA harbors critical water resources that provide drinking water to nearly three million people living in communities located in the Motagua, Ulúa, and Lempa watersheds (Artiga, 2003; UNESCO, 2011); the latter being the largest in the region and crosses the three countries before draining into the Pacific Ocean.

[1] The PTTC was ratified in April 1998, May 1998, and April 1999 by the Congress El Salvador, Honduras, and Guatemala respectively.

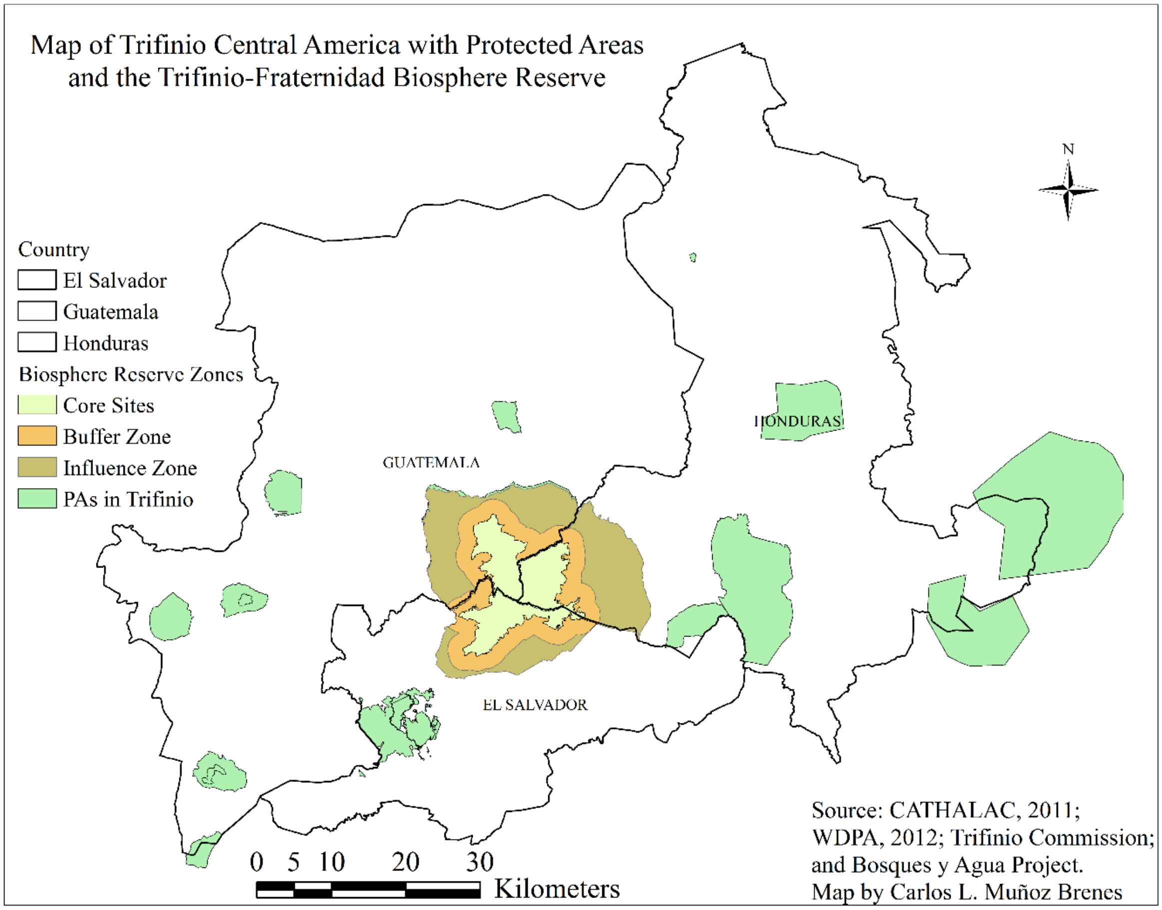

Figure 1.3. Map of Protected Areas in each Trifinio country.

All three countries have established legal statutes to create centralized government agencies that oversee natural resource protection by state and all have a national system of PAs. The legislation in the three countries allows PAs to be co-manage but this should be justified by a technical study. Also, the statutes require that management activities and administrative issues be included in a management, master or annual operation plan (Table 1.2).

There are 16 PAs under state jurisdiction in Trifinio. A complete list of all PAs in Trifinio and additional information is provided in Table 1.4. El Salvador has only three PAs that are part of Trifinio, two relatively large PAs were created in 2007 with strict management and one very small multiuse created in 1986. All six PAs in Honduras were established in 1987, most are large (11,350 ha on average), and only one is categorized as multiuse. Guatemala has seven relatively large PAs within the region. Only one is under strict management but only in its core site. All volcanoes in Guatemala were declared Permanent Closure Zones (PCZ) by Presidential Agreement in June 21, 1956 and resource use restrictions were imposed from the crater to the 30 percent slope—four PAs were created via this statute, the most recent PA was created in 1998 (Figure 1.3). However, a few PCZs were taken off the official list of PAs—including Quetzaltepeque—after the Cadastral Information Registry completed a study on the consolidation of the legal certainty of PAs. Although Copán Ruins Cultural Monument (Honduras) and the private reserve El Pital and the Güija-Metapán lagoon complex (El Salvador) are in Trifinio, these were excluded in the analysis because they are neither forest nor state PAs.

Table 1.2. Legal Structure of PAs by Trifinio Country

Country	Guatemala	Honduras	El Salvador
Agency[2]	CONAP	ICF	MARN
System[3]	SIGAP	SINAPH	SANP
Declared	1989	1992	1998
Statutes	Presidential Agreement in June 21, 1956; Congressional Decree 4-89; Resolution 01-08-2014	General Environmental Law, Decree No. 104-93; Forestry Law Protected Areas and Wildlife Decree No. 98-2007	Forestry Law, 1973; Environmental Law, 1998; Basic Law of Land Reform Decree 153; Decrees 719 and 761; Wildlife Conservation Law, 1994

Data collection

We collected self-reported data on PA governance structure, decision-making processes, management, administration, and conservation outcomes using key informant interviews and a questionnaire with over 35 items. This questionnaire included a ranking of activities from highest to lowest influence on LCLUC within and outside the PA and a ranking of

[2] Consejo Nacional de Áreas Protegidas (CONAP), Guatemala; Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre (ICF), Honduras; Ministerio de Medio Ambiente y Recursos Naturales (MARN), El Salvador.

[3] Sistema Guatemalteco de Áreas Protegidas (SIGAP); Sistema Nacional de Áreas Protegidas de Honduras (SINAPH); Sistema de Áreas Naturales Protegidas (SANP) de El Salvador.

threats and challenges for the PA. We also used two Likert scales with statements related to the level of PA decentralization in decision-making and management capacity measured using five choices—response scores were 1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree (neutral midpoint); 4 = Agree; 5 = Strongly agree; the options of “do not know” or no response were also possible.

We conducted nine key informant interviews with actors directly in charge or working in the 16 PAs included in this analysis. The information provided was complemented with semi-structured interviews with five additional key informants whose work is related to PAs. Key informants are significant holders of institutional knowledge, experiences, and context setting. Bamberger (2009) advises that while each key informant may provide a distinct perspective, which combines objective information with a particular point of view, using a wide range of informants as part of the sample is important in order to include a broad range of experiences and perspectives. This also helps to triangulate information to check for consistencies and to compare the views of different informants. Informants were selected because of their direct responsibility with the PA or their general knowledge about them. Key informants were first contacted via email, Skype or WhatsApp to set up meeting date, time, and place. All meetings took place in the Trifinio countries between September and October 2015 and were voice recorded. The real interview time was between one and two hours but actual contact time was longer for key informants that included a visit to a PA; six PAs were visited during this time. Participation in the interview was consented, voluntary, and confidential. All information collected was transcribed and coded for the analysis.

We used the IUCN categories reported in the World Database on Protected Areas (IUCN & UNEP-WCMC, 2015) to compare PA categories across countries. An equivalency approximation was done for unreported IUCN categories based on descriptions by Dudley et al. (2013) and the national legislation of the country. We classified PAs in two levels of restriction commonly used in the literature: strict and multi-use. This determines the governance structure that affects decentralization, management capacity levels, and in turn PA conservation outcomes. Legislation in the three countries allow some form of co-management which is a variable used to assess decentralization levels (CCAD/PNUD/GEF, 2003; Luna, 1999).

The data collected presents a detailed, qualitative assessment of the selected PAs in the three Trifinio countries on key factors associated with (i) decentralization, distribution of authority for decision-making, and responsibilities for management (e.g., political interference, coordination between agencies, existence of management plan, stakeholder engagement); (ii) management capacity (e.g., administrative structure, staff, budget, funding, data collection), (iii) challenges and threats, local and regional forces, and opportunities, and (iv) how these factors may have changed over time (Table 1.3). The indicators selected are commonly used in assessing decentralization and management capacity (Kishor & Rosenbaum, 2012; Nolte & Agrawal, 2013; Nolte, Agrawal, & Barreto, 2013; Secco, Da Re, Pettenella, & Gatto, 2014).

PA conservation goals are assessed qualitatively using information on the applicability of the management plan or annual operational plan and whether it produces the expected outputs. We collected data on ways management activities deal with threats and challenges from land-use pressures (e.g., land clearing, logging, hunting, grazing, and fire); on ways PA staff deal with and engage key stakeholders (e.g., presence of human communities inside the PA and land use access, participation in decision-making, support to local conservation activities outside the PA, use of local knowledge). We also asked about perceptions on changes in conservation outcomes (e.g., changes in hunting, fires, deforestation) within the boundaries of the PA since its establishment and land use change conditions outside the PA.

Table 1.3. Summary of variables used for PA classification

	Embedded governance structure
Management category	1 = Strict 0 = Multi-use based on nationally designated category mandated by law and standardized using the IUCN system
	Decentralization
Entity responsible for PA (e.g., Secretary or Ministry)	1 = If one central government agency is responsible for PA 0 = If organization co-manager with government agency are responsible for PA.
Appointment of director or person responsible of PA	1 = A central authority appoints the person in charge of the PA 0 = If not 1 = Central authority appoints the person in charge of the PA with local consultation 0 = If not 1 = A local authority appoints the person in charge of the PA in consultation with a central authority 0 = if not
Ways this person makes management decisions for PA	1 = Ordinary daily decisions are made locally and certain general decisions need consultation with central office 0 = If decisions are only made at central office
Participation	The number of stakeholders involved in decision-making and management activities, and whether this number has increased or decreased over time. This includes number of actors, actors' perceptions about the PA, and the involvement of actors in decision-making and management.
Frequency of meetings with external relevant actors	1 = Usually monthly meetings or more according to the need/issue in hand 0 = Never. The magnitude of the relation measured by meetings and the number of years since relevant actors started to meet.
Existence of co-management agreements	1 = If there is co-management agreement 0 = If not
External actors (stated quantity)	Quantity stated or counted
Co-manager	Number of co-managers. The level of decentralization is measured by the existence of co-management agreements and the number of actors involved in management.
Likert scale responses on decentralization	Sum of responses of all Likert statements related to decentralization with higher values indicating more decentralization.
	Management capacity
Existence of written management plan	1 = If there is written management plan 0 = otherwise
Existence of written annual operations plan	1 = If there is an annual operations plan 0 = otherwise
Main sources of funding for PA	1 = National Budget is the main source of funding 0 = Occasionally there is funding from Trifinio Commission projects
Year to year budget fluctuation	1 = Budget does not fluctuate from year to year 0 = Budget fluctuates from year to year mainly with funds from projects
Is current staff enough	1 = If staff is not sufficient for the administration and management of the PA 0 = otherwise.
Data about PA is generated and available	1 = If some data about PA is available 0 = If not
Distribution of budget in percentages	Percentage of budget for salaries
Total paid staff	Number of paid staff
Likert scale responses on capacity	Sum of responses of all Likert statements related to management capacity with higher values indicating more capacity.

Adapted from Kishor and Rosenbaum (2012); Lautze, de Silva, Giordano, and Sanford (2011); McNeely (1995); Munro (1995); Secco, Da Re, Pettenella, and Gatto (2014).

Data analysis

PAs were classified into two levels of restriction—strict and multi-use—by the authors, and we used cluster analysis as described below to generate three levels of decentralization and two levels of capacity. These three classifications of PAs were used to establish descriptive relationships from specific interview questions about conservation outcomes, management practices, stakeholder engagement, ways to deal with threats, and challenges. We used data from Table 1.3 but dropped variables with missing values in more than two observations to increase stability in the cluster analysis solutions. We used Microsoft Excel 2013/2016, AcrMap 10.4, and Stata version 14 for data analysis.

Likert Scale and Likert type Items

The Likert scale on decentralization included nine items and the one on management capacity seven statements. A Likert Scale consists of a series of statements about the attitude object (underlying or latent or natural construct) with positive and negative opinions (Carifio & Perla, 2007). We used items as "ordinal" variables only to estimate average response for each statement (Boone & Boone, 2012; Jamieson, 2004). Total scores for each scale were used to classify PAs by decentralization levels and management capacity—we combined all items in each scale to generate a 'composite' score on decentralization and capacity per country. This is a proper use of the Likert scale with items that are closely interrelated (Joshi, Kale, Chandel, & Pal, 2015). Items in each scale were arranged in a logical sequence. At least one item had an opposite direction in meaning from the overall direction of other items in the scale and its value was reversed before summing the total score (Trochim & Donnelly, 2001)—for example, "PAs are not" rather than "PAs are", in these cases a value of two is converted to four to account for reversibility. Other information on Likert scales is provided in Appendix C.

Cluster analysis

Cluster analysis is a set of methods primarily used in exploratory data analysis to identify patterns, groups, or clusters in data—groupings that make sense based on similarities, dissimilarities, distances or proximity of observations or objects. These methods are useful in assessing whether or not observations that resemble each other can be summarized in a relatively small number of clusters which are different in some way from other clusters (Everitt, Landau, Leese, & Stahl, 2011; Rencher & Christensen, 2013). More detail about this methodology is provided in Appendix C.

Selected variables were range standardized for an application of hierarchical clustering with dissimilarity matrix. The output of the dissimilarity matrix was used with the Ward's-linkage method with Gower's similarity measure because this method works well with groups that are multivariate and have mixed ordered, binary, and continuous data (Everitt et al., 2011; Rabe-Hesketh & Everitt, 2004), and allows missing values in observations. The selection of the number of clusters generated was based on stopping rules like Caliński and Harabasz pseudo-F index and the Duda–Hart Je(2)/Je(1) index and a dendrogram or tree diagram (Everitt et al., 2011; StataCorp, 2015); for details see Appendix C.

We conducted several alternative cluster analysis tests in addition to Ward's for robustness, (e.g., Average, Single and Complete linkages), with and without Likert scale composite scores, and variable standardization combinations. In general, most of the solutions from the cluster methods were very similar cluster solutions to the one reported in this analysis.

Results and Discussion

The final PA classifications consist of (i) two levels of management restriction (strict and multi-use) by standardizing national categories using the IUCN system, (ii) two levels of management capacity (low and high); and (iii) three levels of decentralization (i.e., high, intermediate, and low levels). Results of the cluster analysis for levels of decentralization and management capacity are summarized in Figure 1.4 and Table 1.4. Results from a cluster analysis of the Likert items yielded a similar solution that support this classification.

All PAs were created in three broad periods in the late 1950s, 1980s, and 2000s with 62% established between 1986 and 1987. These PAs are very different in size; two are smaller than 500 ha, 11 are between 1,500 ha and 10,000 ha, and three between 10,000 ha and 30,000 ha. Three PAs (ID 5, ID 7 and ID 15, see Table 1.4) showed classification distortions regardless of the cluster method used. Based on observed characteristics of these PAs and our knowledge about them, this erratic response was unexpected.

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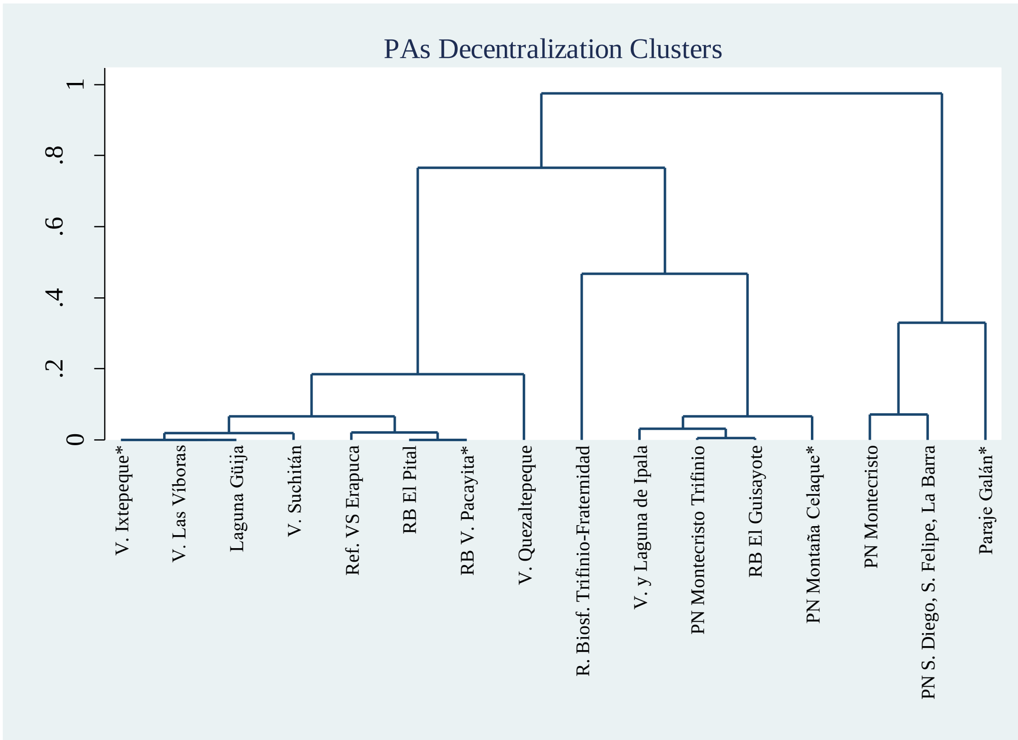

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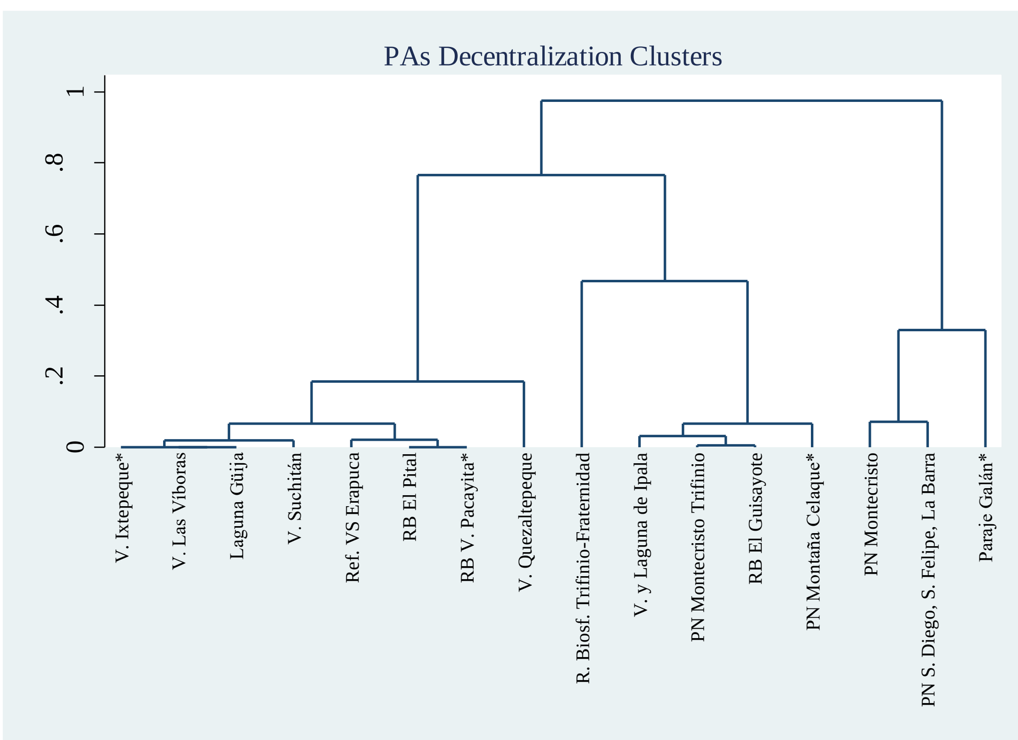

Figure 1.4. Dendrogram solutions with three decentralization and two capacity clusters.

Decentralization

We explore the theoretical idea of the "decentralization trilemma" of governance in Trifinio (see Decentralization Trilemma section). All 16 PAs selected in this study belong to the state. Most PAs in Trifinio were established guided by the ideas of "Planned and managed against people" and "Run by central government" (Phillips, 2002) following the centralization pathway of the trilemma where power and administrative decision-making are allocated to a centralized government agency. While this analysis does not include private reserves that exist in the region, , these lands have never been a state PA, but their existence imply hypercentralization of control on resource use by owners. In addition, the Trifinio countries have made efforts to transfer PA control to community groups (decentralization) by co-management agreements and to local authorities (Municipalization); we also know of at least one co-management being reversed based on national interest.

The cluster analysis for PA decentralization using Ward's hierarchical clustering with variable standardization suggests a solution with three levels based on the variables selected (Table 1.3); having various levels of decentralization supports the idea in the literature that there is not a "pure" decentralization system. The Caliński–Harabasz test does not strongly support this solution but the Duda–Hart tests together with the dendrogram support the construction of three decentralization clusters (Figure 1.4). As such, three PAs are classified in the low decentralization level, eight at the intermediate level, and five are highly decentralized. In Guatemala, five PAs belong in the intermediate level and two high level decentralization, the case in Honduras is half and half, and PAs in El Salvador are all in the low decentralization level. The determining factors for this outcome were the existence of co-management agreements, the number of stakeholders and their participation, and scores on Likert statements related to decentralization.

El Salvador was consistently considered by all key informants to have the most centralized PA system among the three countries. Moreover, in recent years the government decided to take absolute control of PA ID 16 which was for nearly 20 years co-managed by an NGO. The results indicate PAs in Honduras and Guatemala are comparable in terms of decentralization and not a single PA was clustered in the low decentralization level. Although

Guatemala is thought to have the most decentralized system since its forest policy reforms in the late 1990s (Andersson, Gibson, & Lehoucq, 2006; Paulson Priebe et al., 2015), Honduras shows the most decentralization for the case of PAs in Trifinio. A clear indicator of this is that in Guatemala only two PAs have co-management agreements but in Honduras three of the six PAs in the region are co-managed with relatively large numbers of participating stakeholders involved (actors involved in decision-making range from one to 11); PA ID 8 is soon to have a co-management agreement. Finally, the way governance structures in the countries operate is different. Each one of El Salvador's PAs located in Trifinio have a person directly in charge but with strong dependence of the central agency, but PAs in Guatemala and Honduras seem to operate more through deconcentration to the regional offices.

When we consider the Likert items on decentralization, the percentage scores are on average high for positive agreement with most statements. The average score for El Salvador tends to be the lowest across countries with seven out nine items below neutral – a three on the Likert scale; whereas Guatemala has all items above neutral and Honduras has five above neutral. While 78% of informants agree that decision-making is open to participation, only about 34% agree that stakeholders are sufficiently involved in the process, and about 44% agree there is a strong dependency on central authorities for decision-making (Figure 1.5).

Table 1.4. Forest State PAs in Trifinio and Classification by levels of restriction, management capacity, and decentralization

ID	PA Name	Year Declared	Ha.	Category	Management Plan	Co-Management	IUCN Equivalent	Restriction	Capacity	Decentralization
Guatemala										
1	Volcán Ixtepeque*	1956	1659.58	Permanent Closure Zone	No	No	NR (IV)	Multi-use	Low	Intermediate
2	Volcán Las Víboras	1956	2144.22	Permanent Closure Zone	No	No	NR (IV)	Multi-use	Low	Intermediate
3	Volcán Quezaltepeque	1956	332.00	Permanent Closure Zone	No	No	NR (IV)	Multi-use	Low	Intermediate
4	Volcán Suchitán	1956	2539.26	Regional Park and Natural Recreation Area	Yes	No	IV	Multi-use	Low	Intermediate
5	Reserva de la Biosfera Trifinio-Fraternidad	1987	4000.00	Biosphere Reserve	No	Yes	V	Multi-use	Low	High
6	Laguna Güija	1989	1407.73	Special Protection Area	No	No	IV	Multi-use	Low	Intermediate
7	Volcán y Laguna de Ipala	1998	2012.50	Multiple-use Regional Park	Yes	Yes	III	Multi-use	Low	High
Honduras										
8	Refugio de Vida Silvestre Erapuca	1987	6522.00	Wildlife Refuge	Yes	No	NR (IV)	Multi-use	High	Intermediate
9	Parque Nacional Montaña Celaque*	1987	26268.00	National Park	Yes	Yes	II	Strict	High	High
10	Parque Nacional Montecristo Trifinio	1987	8270.00	National Park	Yes	Yes	II	Strict	High	High
11	Reserva Biológica El Guisayote	1987	14081.00	Biological Reserve	Yes	Yes	NR (II)	Strict	High	High
12	Reserva Biológica El Pital	1987	2700.00	Biological Reserve	No	No	NR (II)	Strict	High	Intermediate
13	Reserva Biológica Volcán Pacayita*	1987	10249.00	Biological Reserve	No	No	NR II	Strict	High	Intermediate
El Salvador										
14	Parque Nacional Montecristo	1986	2154.16	National Park	Yes	No	NR (II)	Strict	High	Low
15	Paraje Galán*	2007	24.35	Mixed Use Zone/Area	No	No	NR (IV)	Multi-use	Low	Low
16	Parque Nacional San Diego, La Barra	2007	1916.00	National Park	Yes	No	NR (II)	Strict	High	Low

Notes: * Denotes PA is only partially in Trifinio. Co. = co-management. NR (#) = Not reported (possible equivalent).

Management capacity

PAs can be classified in two levels of management capacity (Figure 1.4 b). Half of the PAs in Trifinio are in the low management capacity level and the other half in the high capacity cluster. All seven PAs from Guatemala and one from El Salvador showed low management capacity and all six PAs from Honduras and two from El Salvador have high (Table 1.4). An analysis of individual Likert items indicates that on average PAs in El Salvador have higher capacity as scores tend to be above neutral with four of seven items, whereas PAs in Guatemala have low management capacity with five out of seven items on or below neutral, and Honduras has only three items that indicate high capacity or above neutral. All key informants disagree 100% that equipment and infrastructure is sufficient for their PA, about 67% disagree that staff is sufficient, and about 89% strongly disagree or disagree that funding is sufficient in Trifinio PAs (Figure 1.5).

The determining factors for high versus low capacity were the existence of a written management plan or operations plan, year to year budget fluctuation, current number of staff, and scores on Likert statements related to management capacity. Several informants highlighted that the Trifinio Commission has funded equipment and other things which have been instrumental for PA operation but not all PAs benefited from these contributions; for example, PA ID 15 and ID 3. Two informants mentioned that PAs in the Trifinio part of Guatemala are not priorities for government agency in charge—with the exception of PA ID 5, therefore, these PAs do not have the required staff, equipment or budget for their effective operation. While PAs in the Trifinio part of El Salvador and Honduras showed the highest management capacity, the former appears to be better off than the latter country. Informants from El Salvador mentioned that PA ID 14 and 16 are among the number one priority PAs over the entire national system because the country has so few PAs compared to the other two.

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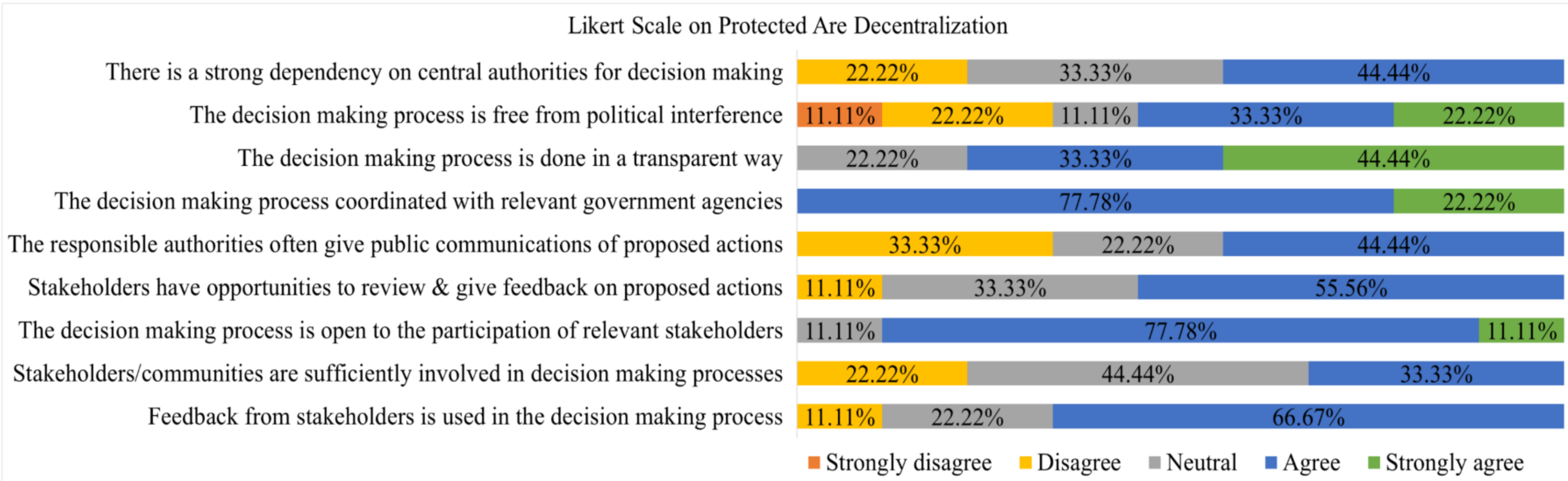


b

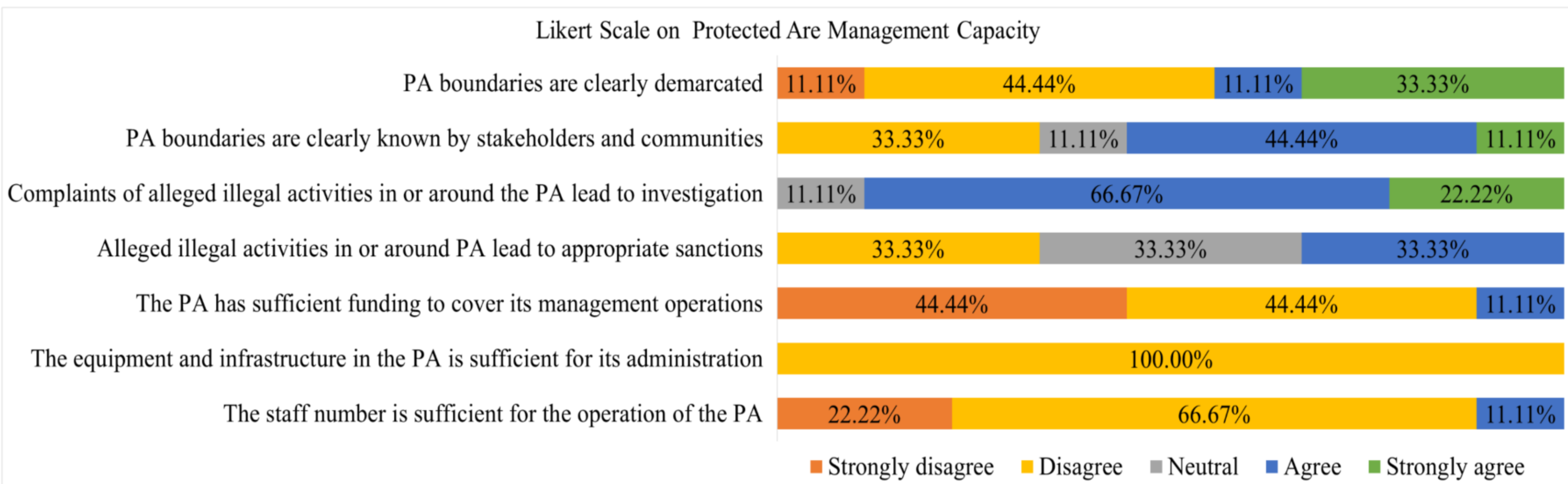


Figure 1.5. Likert Scales on Decentralization (a) and Capacity (b).

Relationships between decentralization, management capacity, and management restriction

Based on the IUCN category system, seven PAs are category IV, one is V, one is III, and seven are II (Table 1.4). Thus, there are nine multiple-use (III, IV and V IUCN category) and seven strict PAs in Trifinio (II IUCN categories). All seven PAs in the Guatemala portion of Trifinio, one in Honduras, and one in El Salvador are multi-use; there are no strict PAs in Guatemala and there are five and two in Honduras and El Salvador respectively.

All seven strict PAs are classified as high management capacity PAs and most multi-use PAs have low capacity levels except for only one in Honduras (PA ID 8). This shows a strong relationship between capacity and restrictive use management categories (Figure 1.2). But this relationship is mediated by priority, as suggested by a key informant—restrictive PAs are giving “priority” and “high preference” for resource allocation which increases capacity to enforce regulations. As explained, having a management plan is an important indication of capacity and most Strict PAs have this management tool. Having this guiding instrument is fundamental when it is well grounded, applicable, frequently revised and updated. Creating the plan requires technical staff expertise or political leverage to get funds to develop it; these are factors related to management capacity. The majority of PAs that have a written plan seem to cluster together into the high capacity group (PA IDs 8, 9, 10, 11, 14, 16).

The relationship between management restriction category and decentralization is more complex (Figure 1.2). Multi-use PAs are classified in all three levels of decentralization, but most (six of them) are classified as intermediate decentralization, only two are highly decentralized, and only one has low decentralization Three strict use PAs have high decentralization, two have intermediate, and two low decentralization levels. We also noticed three PAs have co-management agreements, are strict use, and high decentralization. This supports the idea that in the presence of decentralization policy at a country level, strict management categorization can be associated with more decentralization and this association may affect management capacity in a positive way.

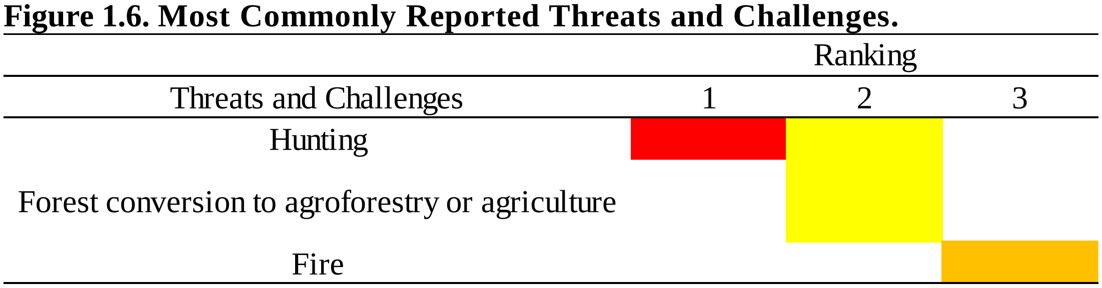
There is also a pattern between management capacity and decentralization in which low capacity and intermediate decentralization are most likely, with five PAs that show this trend. Having a management plan is positively associated with high management capacity and intermediate or high decentralization in four PAs. One possible explanation is that with decentralization there is more participation, especially in management activities stipulated in the plan to be carried out in and outside PAs (e.g., volunteer work in patrolling and protection, reforestation, fire control, and environmental education), and that this positively affects capacity. This could be through training locals in fire control, enforcement, and the importance of protection, or engaging with communities in the buffer zones in mutually benefiting efforts. When stakeholders outside the PAs are engaged, they may soon realize more clearly the positive implications of protection. In the Trifinio context, many PAs are key for water conservation and quality which is a magnet for community engagement. Holding frequent meetings with stakeholders over long periods of time is also a good indicator for participation. In turn all these positively affect the relationship between PAs and communities, reduces conflict, and improve perceptions.

This is a clear indication that there are important factors at the country level that may help explain differences across PAs (Table 1.4). For examples, the PAs in the Trifinio part of Guatemala are all multiple-use with low capacity and with intermediate and high decentralization, lacking management plans. This may be the result of the interaction between a geographic feature and policy process as four PAs were created by an executive order that protects volcanoes. Policy process plays a role for El Salvador where the government has given priority to its flagship PAs in Trifinio "because there are so few and small size PAs in the country". Two PAs from El Salvador have high management capacity, low decentralization and are under strict management categorization; one PA shows a relationship in the opposite direction (i.e., multiple-use, low capacity, low decentralization). However, this PA showed distortions in classification, as such, there is not strong evidence to support that low management capacity is related to low restriction or the opposite in this country. A factor like staff performance plays a role in determining capacity in Honduras where "work is more difficult in PAs in which water is not a priority or key theme". In Honduras we also find a positive association between Strict PAs and high capacity, strict use and intermediate or high decentralization, and high capacity and intermediate or high decentralization; all co-managed PAs with plans showed this pattern very clearly. Nygren (2005) gives a good argument to explain the large number of strict PAs and high centralization in Honduras. This author suggests that mismanagement and overexploitation of forest resources during the 1970s led the government to take a greater role in forest governance by making the state the exclusive owner of forests (nationalization) and centralizing decision-making in the Honduran Corporation for Forestry Development (AFE-COHDEFOR for its Spanish acronym). When not given in concession for tree harvesting, these forest areas created the space for PA establishment. Honduras also demonstrated that in some contexts when there is decentralization there is also high management capacity. These findings suggest a highly non-linear relationship between these three mechanisms (management category, capacity, and decentralization), and further emphasize the role of context in understanding how and why certain governance relationships are observed.

Management capacity, decentralization, and threats and challenges

Key informants qualitatively assessed threats, challenges, and drivers of change in and around their PAs (Figure 1.6). In order of importance, the major drivers reported to cause changes on the land are those affecting the natural and cultural resources. For example, seven PAs report hunting as being the first or second major threat/challenge. Wildlife extraction (e.g., birds, orchid flowers, plants) and conversion from forest to agroforestry systems or to other forms of agriculture were ranked second most important. Outside the PAs, conversion of forest to agriculture (e.g., coffee, agroforestry systems) and hunting ranked highest in eight PAs. For all PAs in Guatemala and El Salvador fire ranked in third place.

Figure 1.6. Most Commonly Reported Threats and Challenges.



According to key informants, the mechanisms that helped reduce threat and challenges and improve management outcomes the most were high capacity and high decentralization. PA staff perceived more positive results when they worked with local communities and stakeholders to confront threats and challenges. Reducing threats and challenges is easier for PAs that have more years engaging with local actors through decentralization processes such as holding meetings with stakeholders more often—when PA staff and stakeholders are engaged there are "more volunteer brigades to reduce fires" and "more coordination in patrolling activities". Nine PAs reported that these strategies help improve conservation goals. Also, close to 68% of key informants agree that feedback from stakeholders is used to inform PA decision-making (Figure 1.5); e.g., local knowledge is used in defining activities in the annual operations plan, research, and monitoring. Key informants for six PAs suggested that when PA staff work with municipal and local authorities to improve roads, access to electricity, and information about incentives and conservation programs, "all this help reduced threats". For one PA lack of access and geographic barriers in accessing the PA was reported as the key to achieving conservation goals.

Implications

Decentralization became a popular policy during the same decade a lot of PAs in Trifinio were created. We see decentralization processes in the region have dealt with both resistance and acceptance. In Guatemala and Honduras—where more examples of deconcentration, delegation, and devolution approaches exists—there needs to be clearer signals of real transfers of power for decision-making and authority or administrative responsibilities to local and regional poles. This is particularly important to create more local management capacity, trust, and increase stakeholder participation.

Our findings suggest that using IUCN management restriction categories as proxy for governance does not fully embrace the complexities of PA governance and conservation outcomes. Restriction category alone has little bearing on this decision-making process. However, PA capacity plays an important role because it has a positive correlation with improvements is outcomes, but this relation is key in situations where the central government is transferring responsibilities and authority—more decentralization along is not sufficient to improve outcomes. We find that strict use is more closely associated with high management capacity with a less clear relationship to decentralization, but we believe the way these two mechanism are affected by restriction and how they affect outcomes depends more on policy processes at the national level (e.g., domestic priorities for which PAs can be decentralized and which ones not, assets allocation). Similarly, the Trifinio Plan has a positive effect in building PA capacity by providing basic equipment, training, and funding the development of management plans and its contribution to decentralization processes is primarily providing a meeting platform for PA cross-country cooperation.

Our findings suggest that context matters a lot in PA management capacity and decentralization. Wilshusen et al. (2002, p. 23) stated, the politicized nature of PAs can help explain conflict and resistance to their establishment and management. While we did not explicitly analyze past conflict, it is a critical moderating factor that determines PA category designation in the traditional classification or categorization systems of PAs (e.g. IUCN). Other confounding variables like policy enforcement and historical, cultural, social, economic, and political context affect management because as Wilshusen stated "the political trajectories of protected areas to a large extent shape how they are perceived by local people and other players, including, most importantly, the degree of legitimacy that management restrictions carry."

Future studies are needed to provide evidence on how these classifications help minimize PA threats and challenges and how they affect conservation outcomes. Our approach in this study was not about discerning "who should" but how decisions over natural resources are made and why. Using other parameters to test hypotheses in relation to protection goals and relating them to findings on capacity and decentralization can help improve theoretical assumptions and fill knowledge gaps related to policy and practical problems in PAs decentralization and set strategies for better policy design and outcomes.

Conclusions

The elements analyzed in our study highlight the complex relationship between governance components such as decentralization, management capacity and management restrictions. This description of the multiple relationships is important for understanding the assumptions and limitations of using IUCN management categories as a measure of governance, and suggests that more in-depth and mixed methods studies will be needed in other parts of the world to fully articulate all the potential pathways between governance and PA outcomes. Our study contributes to decentralization theory and governance process in PAs in relation to their effects on outcomes. More emphasis on this relationship is critical because government agencies in charge of state PAs are confronted with the question of whether more or less decentralized control of PAs can help them be more effective in achieving the conservation goals for which PAs were created. Additionally, studies are needed that specifically assess the relationships and feedbacks between decentralization and capacity, in order to understand how one affects the other across time, which is a missing aspect of our study. This is important because in practice, decentralization of state PAs—in particular decentralization of their natural resources and processes—does not clearly follow the theoretical pathways and idealized outcomes. Our findings also suggest that decentralization processes are not necessarily related to the national management category of a PA, which determines the level of restriction. In sum, researchers and decision makers should pay more attention to the non-linear and complex linkages between decentralization, management capacity, and management category if the goal is to improve our understanding of the role of governance in PA outcomes.

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Chapter 2 An Evaluation of the Impact of Protected Area Governance on Land Cover Outcomes

Abstract

Protected areas (PAs) are a prominent approach to minimize negative impacts from land cover and land use change (LCLUC). A critical question for evaluating the effectiveness of PAs is whether and how different governance mechanisms help PAs prevent LCLUC. We conducted an impact evaluation of 15 PAs to assess whether PA governance mechanisms are associated with LCLUC in Trifinio, Central America. We classified these PAs by levels of restriction, decentralization, and capacity using secondary and primary data. Our outcome variable was the percent annual rate of change in Normalized Difference Vegetation Index (NDVI) over seven epochs from 1986 to 2016 measured at 30 m resolution pixels. We used Propensity Score Matching and selected biophysical and socioeconomic covariates to estimate the average treatment effect on the treated for different governance classifications of PAs on NDVI across epochs. On average, strict PAs had a larger positive impact than multiple-use PAs on changes in greenness. We also found that low decentralized PAs achieved higher levels of impact on greenness and low capacity PAs showed little impact compared to high capacity PAs. We detected two broad patterns in outcomes from the PA classifications. One where multi-use, high decentralized, and low capacity PAs tend to follow a similar pattern with little impact on outcome across time. The other shows higher levels in impact across time from strict use, low decentralization, and high capacity PAs. We found considerable heterogeneity of impact across epochs; this is potentially due to unobserved confounding factors that affect the probability of allocation of pixels into the treatment groups. This study contributes broadly to land use and governance theory by assessing assumptions around LCLUC drivers and the role of conservation governance. The research findings are important to inform local conservation policy and advance theory about how governance affects PA outcomes on the ground.

Introduction

Protected areas (PAs) are critical to global conservation goals related to biodiversity and cultural and natural resources. PAs are spaces created to protect biodiversity, ecosystems, and ecological processes or to minimize degradation of natural resources (e.g., forest and water) and enhance ecosystem services. Many PAs contain features of earth geological processes, cultural values, and landscapes (Dudley et al., 2013). Recently policy makers also expect that PAs will contribute to achieving socioeconomic goals related to livelihoods, human well-being, boosting local and national economies from tourism activities, and helping in climate change mitigation, adaptation, and resilience (Watson, Dudley, Segan, & Hockings, 2014).

PAs are land and water spaces designated as national park, nature reserve, wilderness area, and community conserved areas. The International Union for Conservation of Nature (IUCN) groups PA designation in six management categories, ranging from highly strictly protected sites with highly restricted access to people, to multiple-use areas that have more open access and have fewer restrictions and integrate sustainable resource use with conservation (Dudley, 2008). As national PAs categories are defined according to national management objectives, conservation practitioners use the IUCN classification system for standardization of PAs.

About 15.4% of the earth's terrestrial surface and 3.4% of the global ocean area has been set aside and designated under some type of State PA management category—the World Database of PAs (WDPA) version for April 2016 registered a total of 217,155 designated PAs in 244 countries and territories (202,467 terrestrial and 14,688 marine) and by December 2016 the record was 232,128 (IUCN & UNEP-WCMC, 2016; UNEP-WCMC & IUCN, 2016). Some 5.4 billion ha (86%) of global forests is State protected and regulated by public governance structures, about 10% is under private ownership, and 4% in other forms of management such as communal lands (Agrawal et al., 2008).

Decision-making among key actors affects natural resources management, governance, and land cover and land use change (LCLUC) which influence PAs outcomes (Lambin et al., 2014). An understudied area of research related to LCLUC is exploring the impacts of governance on LCLUC. This involves evaluating impacts from conservation policy and decision-making by analyzing the interactions between an intervention (e.g., creation of PAs and other conservation measures) with governance and subsequent land cover outcomes (Lambin et al., 2014). It also requires understanding the theory of change behind land use drivers, or the root of the causes of how change unfolds (Taplin & Clark, 2012).

An important global decision by Parties to the Convention on Biological Diversity (CBD) in its Strategic Plan for Biodiversity 2011-2020 and Aichi Biodiversity Targets plans is to halt the loss of biodiversity so that "ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication" (CBD, 2010, p. 8). Specifically, Target 11 states that Parties commit that by 2020, at least 17% of terrestrial and inland water areas, and 10% of coastal and marine areas, are conserved in ecologically representative, effectively and equitably managed, and well connected systems of PAs and by other conservation measures that are also integrated into the wider landscapes and seascapes. Also, by 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan (Target 17). The new conservation wave promoted by the CBD will increase terrestrial and marine protection by nearly 2% and 7% respectively. This is to be done by means of PAs, habitat restoration, species-recovery programs, and other targeted conservation interventions.

Despite global commitments under the CBD, the effectiveness of existing PAs is hindered by underlying processes and direct pressures from poor management, lack of funding and planning, reductions in staff, dire infrastructure, unenforced legislation, and outside threats (UNEP-WCMC & IUCN, 2016; Watson et al., 2014). Other major impediments to fulfilling national conservation obligations are lack of resources and institutional limitations (Aguilar-Støen & Dhillion, 2003). Even with the growth in global numbers of PAs worldwide deforestation continues at a disturbingly high rate. At the global level nearly 13 million hectares were deforested per year in the last decade compared with 16 million hectares per year in the 1990s (FAO, 2006, 2010).

The scarcity of resources and continued loss of forest within existing PAs demand a clear understanding of what factors affect impacts and conservation outcomes for future PA creation. There is a clear need for rigorous studies to evaluate the effectiveness of PAs and what factors lead to effectiveness. Most PA impact evaluation (IE) studies focus on explanatory variables related to biophysical characteristics (e.g., climate and topographic), and socioeconomic conditions (e.g., economic returns to agriculture and pasture, lower costs of clearing land, distance to roads and markets) and assess impacts on outcomes in terms of temporal and spatial changes in forest cover (Ferretti Gallon & Busch, 2014; Geldmann et al., 2010). More recently, the conservation field has applied rigorous IE methods using PA restrictions as proxy for governance structures but restrictions are not equivalent to governance (Nolte, Agrawal, Silvius, et al., 2013; Pfaff et al., 2013). Governance is not management—governance is the set of processes and institutions that help define management goals. Management is about implementing the practical measures to achieve those goals, its aim is to improve outcomes directly while governance seeks to define what good outcomes are and sets the decision-making process of management activities to achieve those goals (Lautze et al., 2011). As such, PA governance is about who decides their objectives, how and with what means to pursue them; how decisions are taken; who holds power, authority and responsibility; and who is accountable.

This study is an IE of PAs in Trifinio Region of Central America from 1986 to 2016. The Trifinio Region includes areas of Guatemala, Honduras, and El Salvador. The first objective is to examine how impact on outcomes changes across 15 PAs by level of restriction defined by their management category standardized according to the IUCN classification. The second objective is to test if there is variation in PA impact by levels of decentralization and management capacity. While the first objective is commonly performed in impact studies of PAs, the factors analyzed as part of the second objective are key to understand PA outcomes because they are embedded in PA governance processes and design, but few studies have been done on understanding how these factors are associated with PA outcomes (Macura et al., 2013, 2015). Thus, this study not only estimates the average treatment effect on protected sites from protection across space and time, the causal effect from different classifications described above are disentangled to assess the effects of governance on outcomes. The methodological approach used is to combine quantitative and qualitative data in a quasi-experimental design to match protected to unprotected spaces (Blackman, 2013; Ferraro, 2009; Jones & Lewis, 2015). We used remote sensing data of Normalized Difference Vegetation Index (NDVI) to calculate the annual average speed at which the greenness of land cover changes with panel data from 1986 to 2016 in the Trifinio Region of Central America. Findings from this analysis contribute to a small but growing number of rigorous IEs of PA effectiveness and provide much needed empirical estimation of the role of PA governance in achieving PA outcomes.

Methods

Study area

Current LCLUC in Central America can be tracked back to the 1950s. Present landscape characteristics in the region are the result of path-dependent conditions and decisions made at critical juncture points that enabled institutional formation that fundamentally affected structural development and long-run trajectories of change (Mahoney, 2000, 2001). The rapid patterns of change were linear between 1950–1986 and the rate of deforestation was estimated to be 400,000 ha per year in the 1970s and about 300,000 ha by 1990. Most forest areas in the region (Figure 2.1) were converted to cotton or cattle fields driven by favorable markets, subsidies, road construction, land and tenure reforms, technological change, low cost in timber values, political stability, and tradition—although subsistence farming, banana and coffee plantations played important roles as well (Kaimowitz, 1996; Williams, 1986). During the 1970s and 1980s colonization was the most important driver of deforestation, but had no effect by the 1990s (Rudel, 2005). Rudel highlights that regrowth—particularly secondary forests—may explain a decline in net deforestation by the 1990s. More recently subsistence and commercial agriculture, cattle ranching, and population growth in marginal areas are key drivers of change, but forest plantations are of little significance in the region (Bray, 2009).

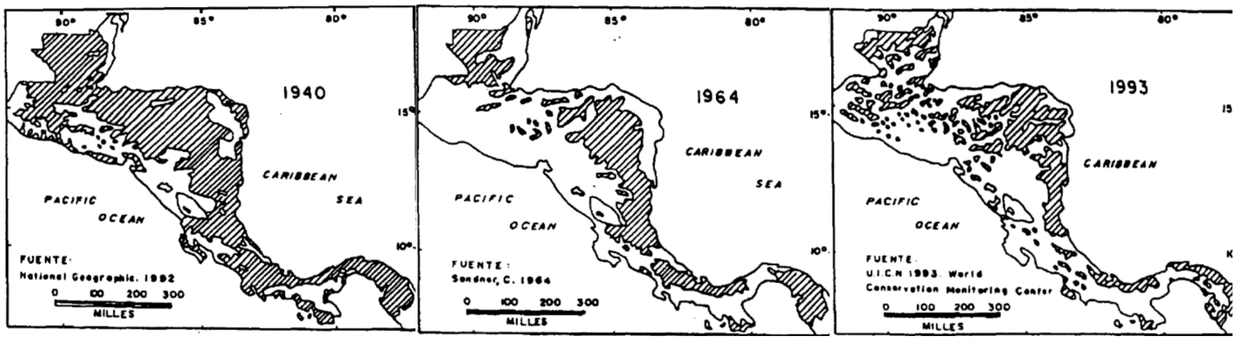

Figure 2.1. Forest Areas in Central America in 1940, 1964, and 1993.
Adapted from Kaimowitz (1996).

Central America is a biodiversity hotspot home to 12% of the world's known species. With about 670 PAs the extension of protection expands nearly 12.4 million ha or close to 24% of land area (Figure 2.1). Most PAs are small with a size of about 15,000 ha (about 83% of the total), only about 4% of the areas are bigger than 100,000 ha and were created in the 1980s and 1990s. Creating terrestrial PAs in the region has always been a challenge due to forest fragmentation, political challenges, and the high costs of natural resource protection (Holland, 2012). The establishment of PAs was enhanced when in 1989 the presidents and heads-of-state of the Central America countries signed the "Charter Agreement for the Protection of the Environment", which established the Central America Commission for Environment and Development (CCAD, 1989). Although many of these PAs are small, fragmented, isolated, or poorly protected (Holland, 2012; Myers et al., 2000) there is some evidence of their impact. Studies on the evaluation of the impact of PAs on deforestation in Costa Rica found that, on average, PAs reduced deforestation by approximately 10% by preventing forest loss in areas that would have been deforested in the absence of PAs (Andam et al., 2008). Andam, Ferraro, Sims, Healy, and Holland (2010) studied PAs in Costa Rica and Thailand and found that while communities located near PAs are substantially poorer than national averages, these differences cannot be attributed to protection, in fact the authors argue the net impact of PAs was to alleviate poverty.

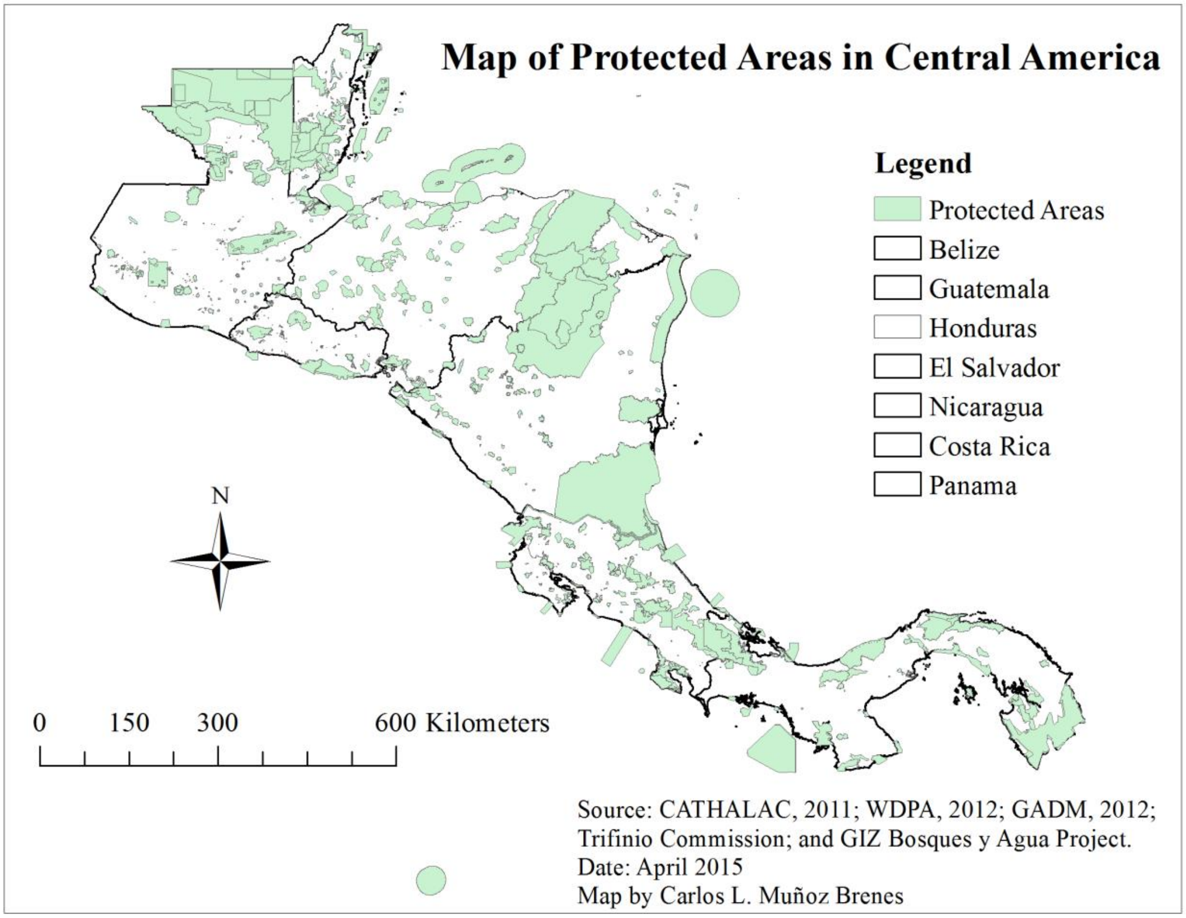

Figure 2.2. National and transboundary PAs in Central America.

State Protected Areas in Trifinio

The Trifinio region is an area of nearly 750,000 ha in northern El Salvador (15%), southern Guatemala (45%), and western Honduras (40%). Trifinio was created by international agreement between these countries as a political administrative unit after the peace accords signed on 7 August 1987. As a result the Plan Trifinio Tri-National Commission (PTTC) was created and ratified in March 1998, May 1998, and July 1999 by the Congress of each country respectively (OAS, 1993). Population estimates show that the region has grown from 572,000 to nearly 900,000 between 1987–2011 (Schlesinger, Muñoz Brenes, Jones, & Vierling, 2016).

This study focuses on 15 forest PAs located in Trifinio—six PAs are in Guatemala, six in Honduras and three in El Salvador—with a wide range of management categories; one PA that protects a waterbody was excluded. The smallest PA is less than 25 ha and the largest is 26,268 ha (Table 2.1). Most were established by 1987 when the peace accords were signed, with two established in the 2000s.

Table 2.1. Summary of Protected Area Characteristics.

ID	PA Name	Declared Year	Area Ha.	Management Category	IUCN Equivalent	Restriction	Capacity	Level Decentralization
				Guatemala				
1	Volcán Ixtepeque*	1956	1659.6	Permanent Closure Zone	(IV)	Multi-use	Low	Intermediate
2	Volcán Las Víboras	1956	2144.2	Permanent Closure Zone	(IV)	Multi-use	Low	Intermediate
3	Volcán Quezaltepeque	1956	332	Permanent Closure Zone	(IV)	Multi-use	Low	Intermediate
4	Volcán Suchitán	1956	2539.3	Regional Park and Natural Recreation Area	IV	Multi-use	Low	Intermediate
5	Reserva de la Biosfera Trifinio-Fraternidad	1987	4000	Biosphere Reserve	V	Multi-use	Low	High
6	Volcán y Laguna de Ipala	1998	2012.5	Multiple Use Regional Park	III	Multi-use	Low	High
				Honduras				
7	Refugio de Vida Silvestre Erapuca	1987	6522	Wildlife Refuge	(IV)	Multi-use	High	Intermediate
8	Parque Nacional Montaña Celaque*	1987	26268	National Park	II	Strict	High	High
9	Parque Nacional Montecristo Trifinio	1987	8270	National Park	II	Strict	High	High
10	Reserva Biológica El Guisayote	1987	14081	Biological Reserve	(II)	Strict	High	High
11	Reserva Biológica El Pital	1987	2700	Biological Reserve	(II)	Strict	High	Intermediate
12	Reserva Biológica Volcán Pacayita*	1987	10249	Biological Reserve	II	Strict	High	Intermediate
				El Salvador				
13	Parque Nacional Montecristo	1986	2154.2	National Park	(II)	Strict	High	Low
14	Paraje Galán*	2007	24.35	Mixed Use Zone/Area	(IV)	Multi-use	Low	Low
15	Parque Nacional San Diego, San Felipe, La Barra	2007	1916	National Park	(II)	Strict	High	Low

Notes: * Denotes PA is only partially in Trifinio. Co. = co-management. For Not Reported PAs (Roman number possible equivalent).

Data Collection

Protected Area Classification

PAs differ across the three countries in terms of national management categories naming conventions. For example, PAs with different categories (reserve, refuge, mixed zones) share similarities in management and restrictions practices. To standardize permissible uses, PAs are classified by levels of restriction based on the reported class in the World Database on Protected Areas and for unreported PAs the IUCN system is used to identify an equivalent (IUCN & UNEP-WCMC, 2016). The restriction class has two levels—strict and multi-use (Table 2.1). PAs in IUCN categories I and II are mainly created for science, wilderness protection, ecosystem protection, and recreation, and are in the “strict” restriction level, and PAs in IUCN categories III to IV are established largely for conservation of specific natural features, sustainable use of natural resources, or require management intervention and are in the “multi-use” restriction level.

PAs are classified in three levels of decentralization and two levels of management capacity. These classifications were constructed using primary data from thirteen key informant interviews of PA staff, managers, and co-managers—nine informants directly work in PAs as managers or staff, and five informants support activities related to the PAs or were former staff. The interview included 35 questions about aspects of governance structure, decision-making processes, management, administration, and conservation outcomes. Additional information on decentralization in decision-making and management capacity was collected using two Likert scales; these data were complemented with semi-structured interviews with a former PA staff and a Trifinio Commission staff (Table 2.1).

Protection through forest state PAs (the treatment) is evaluated by their classification in levels of restriction, decentralization, and management capacity—thus, these classes represent intermediate treatments (intervening causes) that affect the outcomes (Ferraro & Hanauer, 2015). Based on our key informant interviews and experience in the study area these variables are not treated as endogenous in this study but considered instead as variations in treatment that potentially influence the effectiveness of the PA in achieving its intended outcomes. The explicit assessment by levels helps disentangle the causal effects on the outcome of interest from these variations in treatment to avoid the confounding effect from the nonrandom treatment assignment.

Remotely sensed and GIS data

Medium resolution remotely sensed Landsat images for Trifinio were acquired from the USGS Earth Resources and Observation Science Center (USGS/EROS) as surface reflectance values to develop least-cloud, approximately five-year, epochs of vegetation index-based greenness-based land cover and land use (GLCLU) data that could be measured over time to better understand vegetation disturbance and regrowth; GLCLU data are being used as a proxy to measure the extent of vegetation greenness change. We use greenness as the metric for transition rather than land cover class type, due to the spectral similarity between coffee and agroforestry systems. The area of Trifinio comprises a single Landsat scene (World Reference System (WRS) Path/Row 19/50) per epoch. The source data had already been orthocorrected to the most accurate geometric and topographic level (L1T), radiometrically and atmospherically corrected via the Landsat Ecosystem Disturbance Adaptive Processing System (Masek et al., 2013) and processed to a cloud-shadow Fmask (Zhu & Woodcock, 2012) through the USGS/EROS Science Processing Architecture Climate Data Record (CDR) program (USGS, 2016). Fmask data were re-classed to Boolean layers—for USGS/EROS these are provisional data because the code is subject to change.

As these data are passively-sensed and cloud cover is an issue in the region, least cloud data are only feasibly accessible during the dry season (between January and March), which is a difficult time to assess green vegetation; however, there is no other option for this region. The cloud and shadow Fmask Boolean layers were used to mask out the compromised image sectors from all processing and analyses streams. After cloud masking, all raster images and vector data files were resampled to a common raster grid using the Universal Transverse Mercator (UTM) Zone 16N using the WGS1984 datum, while maintaining the original Landsat resolution of 30 meters, using remotely sensed image processing tools (ArcGIS, v. 10.3; ENVI "ENvironment for Visualizing Images" *v. 5.3.1*; and TerrSet v.18.21; TerrSet's SAMPLE.exe). NDVI layers were prepared to create ranked greenness in quintile-based categories (Rouse, Haas, Schell, & Deering, 1973). When more than one image made up an epoch, least cloud images were formed by combining them into epochs using maximum NDVI value criteria (Annex B). For example, the maximum value of NDVI will be the output of three very cloudy images, only after all clouds and shadows have been removed by masking. Epochs may be made up of data from an adjacent year if it is in the same dry season period, nearest the month of March. Pixels classified as water were combined in a single water mask to remove all water pixels across all images to prevent water-related false transitions. The original range of Surface Reflectance (SR) data were from -10,000 to +20,000 (scaled to Real reflectance values with a factor of 0.0001), however valid data are only held in those values between -10,000 and +10,000, and thus data were capped at 0 and +10,000 to assess greenness.

Only pixels that comply with the selection criteria of being free of clouds, shadows, and water bodies, and have no missing data across time and space were sampled inside and outside PAs in Trifinio to measure changes in greenness. For PAs less than 50 ha, 50% of pixels, and for PAs larger than 50 ha, 10% of pixels, were randomly selected, yielding more than 27,000 protected or "treated" pixels. Pixels outside PAs were sampled at 10% yielding slightly less than 700,000 pixels as "control" units. A database of the sampled pixels has been prepared in MS Excel and GIS with best available data of the relevant covariates (Annex B). We also measured elevation, slope, distance to roads, distance to PA boundary, and distance to municipality capitals and distance to national capitals for each pixel (Table 2.2).

Table 2.2. Variable description and unit of measure for pixel level relevant covariates.

Variable	Variable description
Restriction	PA restriction levels; 0 = not PA, 1 = Strict use, 2= Multi-use
Decentralization	PA decentralization levels; 0 = not PA, 1 = Low, 2 = Intermediate, 3 =High
Capacity	PA management capacity levels, 0 = not PA, 1 = Low, 2 = High
Elevation	Elevation in meters above sea level (masl) of a sample pixel
Slope	Percentage slope of a sample pixel
Distance to PA	Distance to the nearest PA border in meters
Distance to Road	Distance in m from the centroid of a pixel to the nearest road
Distance to Municipal Capital	Distance in km from the sample pixel to the municipality's capital
Distance to National Capital	Distance in km from the pixel to the national capital city
NDVI	NDVI value of the pixel in that year; 1986, 1991, 1996, 2001, 2003, 2011, 2016
rNDVI	Annual rate of change in NDVI of a pixel in an outcome period in percentage
aNDVI	Annual change in NDVI of a pixel in an outcome period in percentage

Data Analysis

Following Blackman (2013) terminology on impact evaluation, the unit of analysis is a 30 m by 30 m pixel, the outcome period goes from 1986 (baseline year) to 2016. The treatment variable is a dichotomous measurement on whether the pixel is exposed to protection or not. The treated unit is a pixel in a PA and a control unit is a pixel outside a PA. The outcome variable is longitudinal data of NDVI values measured in 1986, 1991, 1996, 2001, 2003, 2011, and 2016. The annual change in NDVI (aNDVI) in percentage was calculated for the seven outcome periods using NDVI values from one year measurement to the next—one overall outcome period and six intermediate periods (i.e., 1986-2016, 1986-1991, 1991-1996, 1996-2003, 2003-2011, 2011-2016); aNDVI was calculated using the formula from Puyravaud (2003, p. 595) included in Appendix A.

Matching strategy

Quasi-experimental IE methods were used to control for the non-random allocation of protection and to reduce bias in the estimated impacts. To accomplish this a counterfactual is needed to estimate the mean difference between the outcome with intervention (i.e., PAs) and the outcome without protection from PA creation. A counterfactual in a quasi-experimental design is a comparison of the condition with what would have occurred in the absence of the intervention, but this is impossible to observe (Ferraro, 2009). Thus, results on the outcome variable are used to estimate the impact in terms of Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATT) between treated pixels and control pixels, and to detect variation in impact across space and time. The ATE is the mean of the difference between treated units (Y_t) and control units (Y_0) that were not exposed to the treatment; $\tau_t = E(Y_t - Y_0)$. The ATT is conditional to only those units getting the treatment $\Delta_t = E(Y_t - Y_0 \mid t = 1)$ (Imbens & Wooldridge, 2009; Khandker, Koolwal, & Samad, 2010).

This is a robust approach to measure the causal effect of a conservation policy on LCLUC informed by longitudinal remote sensing data and qualitative data on PAs governance characteristics. The outcome variable (i.e., vegetation greenness or NDVI) is a proxy to measure changes in vegetation "health" and degradation between epochs. The control variables are elevation, slope, distance to roads, and distance to municipality capitals and distance to national capitals (Table 2.2). Several studies have demonstrated a strong effect of these covariates on the treatment and the outcome (Andam et al., 2008; L. Joppa & Pfaff, 2010; L. N. Joppa & Pfaff, 2009; Wendland et al., 2015).

The naïve difference in NDVI outcomes between treatment and control units is likely biased due to the nonrandom allocation of PAs as treatment. Matching is used to reduce selection bias when estimating the impact that can be attributable to PA creation in the presence of systematic differences between protected pixels and control pixels or the counterfactual units. Matching involves pairing treatment and comparison units that are similar in terms of their observable characteristics (Rubin & Thomas, 1996). Propensity score matching (PSM) is one matching technique used in the evaluation of treatment effects (Rosenbaum & Rubin, 1983). Pixels in the treatment groups are matched based on the propensity score (PS) or the estimated probability of exposure to the treatment conditional on observed characteristics shared by all units in the two groups (for observed control variables, see Table 2.2). Matched pixels from the treated and untreated groups have similar PS values and are used to create a sample dataset of treatment and control units to evaluate the impact of PAs on changes in NDVI. This is done for each category of PA restriction, decentralization, and capacity (Table 2.1), resulting in six sub-datasets analyzed over seven time epochs.

PSM allows balancing the distributions of observed characteristics between the treatment and control groups and by controlling on these covariates bias is reduced—this is the balancing property of PS (Rubin & Thomas, 1996). PSM works under the assumption of strong ignorability in treatment assignment (i.e. no unobserved confounders affect PS), which states that treatment assignment and the outcome are conditionally independent of covariates used to create the PS. Also, PSM assumes pixels with the same covariate values have a positive probability of being in the treatment and control groups—the common support or overlap condition (Caliendo & Kopeinig, 2008; Pan & Bai, 2015). The lack of counterfactual is resolved by using matched data on PSs where the matched units in the control group have a similar probability of being treated as the probability of corresponding units in the treatment group. Thus, the ignorability conditional on observed covariates is applicable to the PS if a unit in the treatment group and a corresponding matched unit in the control group have the same PS—these matched units will have the same values in the covariates producing unbiased estimates of the treatment effects and reduced selection bias from balancing the distributions of observed covariates between the groups. A third key assumption in PS analysis is the stable unit treatment value assumption (SUTVA; Rubin, 1980, 1986)—observed values in the unit of analysis are independent of treatment assignment to the other units—commonly understood as contamination (Pan & Bai, 2015).

Estimating the Propensity Score

PS estimations require a multivariable bivariate logit or probit model specification to estimate the PS conditioned on covariates. In this study we used a logit model with treatment being the treatment status of a pixel (i.e., PA status) and the independent variables are as in Table 2.2. A matched sample was then created by matching treated and untreated units on the predicted PS using a caliper band of 0.2 times the standard deviation of the PS. A caliper of less than or equal to 0.25 of the standard deviation of the PSs is sometimes used, but Austin (2011) suggests 0.20 is the optimal caliper bandwidth and will eliminate approximately 99% of the bias due to the measured confounders and minimizes the mean squared error of the estimated treatment effects. Pairs of treated and untreated pixels were matched in this study using 1:1 nearest neighbor matching.

The quality of the match and covariate balance after matching were evaluated. The quality of the match is a test of balancing properties of the estimated PS to assess similarity in the distribution between PSs of comparison groups over defined “blocks” across the PS observed range. Balance refers to similarity in covariates across the matched treatment and control groups. While imbalance in some covariates can be expected, balance in theoretically important covariates is more important than balance in covariates that are believed to have less impact on the outcome (Garrido et al., 2014). The balance evaluation can be done statistically through percentage bias reduction (PBR) on the covariate. A proposed maximum standardized difference for specific covariates may range from 10% to 25% (Cochran and Rubin's rule of thumb) and a standard difference of less than 10% indicates a negligible difference in the means (Austin, 2009, 2011; Cochran & Rubin, 1973). Furthermore, if a standardized bias is reduced to below 5% after matching, the matching method is considered to have achieved effective balance in the distributions of the covariate and an 80% of PBR can be reasonably considered as a sufficient amount of bias reduction (Pan & Bai, 2015). Balancing can also be assessed graphically using histograms, box plots, or quantile-quantile plots.

After units in the comparison groups are matched, the unmatched comparison units are discarded and are not directly used in estimating the treatment impact (Dehejia & Wahba, 2002). The treatment effect after matching (i.e., ATE or ATT) can be estimated by the differences in means across the matched treatment and control groups. Alternatively, post matching regression can be used to estimate the treatment effect when bias-adjustment is recommended (Jones & Lewis, 2015). In this study we used matching regression analysis with robust standard errors—where aNDVI for a given period is the dependent variable and the regression covariates are those listed in Table 2.2. We do this for each of the six sub-datasets and each period outlined above. All matching estimates of ATE and ATT were generated using Stata 14.2 commands psmatch2 version 4.0.11 and teffects psmatch.

Results

The treated group has 26,740 PA pixels and the control group has 133,705 (five times as many treated pixels) for a total of 160,445 pixels; these are the full set of pixels randomly selected from the raw dataset and comply with the selection criteria. For all pixels in this dataset the average elevation is 1,145 m, slope is 31%, distance to the nearest PA is 7.5 m, distance to roads is 2 km, distance to the municipality capital is 8.6 km, and distance to the national capital 166 km. The distribution of pixels varies by country with nearly 23% located in Guatemala, 63% in Honduras, and 14% in El Salvador—these proportions are the same for protected and not protected pixels.

The covariate values between PA and not PA pixels are on average very different. For example, on average PA pixels are located at higher elevation, steeper slopes, further from roads, and closer to municipality and national capitals compared to not protected pixels. NDVI values in the range of 0.2 to 0.5 generally correspond to sparse vegetation, shrubs and grasslands or senescing crops whereas dense vegetation like temperate and tropical forests or crops at their peak growth stage show higher values between 0.6 to 0.9 (Simonetti, Simonetti, & Preatoni, 2014). Average NDVI value across 1986-2016 for not PA pixels is 0.56 and 0.66 for PA pixels (Table 2.3).

Table 2.3. Summary of descriptive statistics**.**

Statistic	Mean	Min	Max
Not PA, n = 133,705			
Elevation	1041	268	2469
Slope	29.65	0	197.7
Dist PA	8.4	0.03	32.65
Dist Road	1867	0.03	15899
Dist Mcap	8.690	0	64.38
Dist Ccap	167.9	51.42	238.2
NDVI 1986	0.526	0.200	0.886
NDVI 1991	0.547	0.200	0.894
NDVI 1996	0.538	0.200	0.879
NDVI 2001	0.549	0.200	0.895
NDVI 2003	0.562	0.107	0.921
NDVI 2011	0.587	0.200	0.883
NDVI 2016	0.608	0.0718	0.929
PA, n = 26,740			
Elevation	1663	429	2533
Slope	38.62	0	209.5
Dist PA	2.81	0	7.280
Dist Road	2704	0.01	10859
Dist Mcap	8.180	0	53.56
Dist Ccap	156.1	66.57	236.4
NDVI 1986	0.622	0.200	0.887
NDVI 1991	0.652	0.205	0.895
NDVI 1996	0.635	0.201	0.896
NDVI 2001	0.648	0.203	0.882
NDVI 2003	0.687	0.189	0.927
NDVI 2011	0.696	0.230	0.905
NDVI 2016	0.724	0.169	0.934
All pixels, n = 160,445			
Elevation	1145	268	2533
Slope	31.15	0	209.5
Dist PA	7.47	0	32.65
Dist Road	2006	0.01	15899
Dist Mcap	8.6	0	64.38
Dist Ccap	165.92	51.42	238.2
NDVI 1986	0.542	0.200	0.887
NDVI 1991	0.565	0.200	0.895
NDVI 1996	0.554	0.200	0.896
NDVI 2001	0.566	0.200	0.895
NDVI 2003	0.583	0.107	0.927
NDVI 2011	0.605	0.200	0.905
NDVI 2016	0.628	0.0718	0.934

Before PSM, the mean aNDVI values vary considerably across epochs and between treatments groups (Table 2.4). NDVI increased at an average speed of 0.28% per pixel per year for the 30-year period, with a higher change in PA pixels (0.34%) compared to control pixels (0.27%) between 1986-2016. Most outcome periods have a positive change in greenness, with the lowest positive change being 0.27% NDVI in 2003-2011 and the highest change at 0.84% between 2001-2003. The aNDVI is negative, however, for all pixels in 1991-1996 indicating a reduction in NDVI (-0.21%).

Table 2.4. Annual change in NDVI (aNDVI) in percentage per outcome period before matching**.**

aNDVI	Epoch	Mean	VAR	SD	Median	Min	Max
Not PA	1986-2016	0.274	0.151	0.388	-2.028	0.272	2.066
	1986-1991	0.417	3.308	1.819	-10.17	0.440	11.14
	1991-1996	-0.189	2.294	1.515	-11.00	-0.230	10.54
	1996-2001	0.234	2.430	1.559	-10.46	0.206	11.25
	2001-2003	0.623	18.13	4.257	-31.48	0.575	27.77
	2003-2011	0.309	1.691	1.300	-6.460	0.204	6.931
	2011-2016	0.437	3.862	1.965	-11.30	0.692	11.01
PA	1986-2016	0.341	0.151	0.389	-1.533	0.312	2.050
	1986-1991	0.592	3.048	1.746	-10.59	0.642	10.36
	1991-1996	-0.337	2.784	1.668	-11.25	-0.258	8.124
	1996-2001	0.265	2.143	1.464	-9.300	0.222	10.66
	2001-2003	1.952	18.88	4.345	-19.90	1.855	21.27
	2003-2011	0.113	1.210	1.100	-5.480	-0.135	5.386
	2011-2016	0.566	2.962	1.721	-9.396	0.950	9.510
All pixels	1986-2016	0.285	0.151	0.389	-2.028	0.280	2.066
	1986-1991	0.446	3.269	1.808	-10.59	0.486	11.14
	1991-1996	-0.214	2.379	1.542	-11.25	-0.234	10.54
	1996-2001	0.239	2.382	1.543	-10.46	0.208	11.25
	2001-2003	0.845	18.50	4.301	-31.48	0.850	27.77
	2003-2011	0.276	1.616	1.271	-6.460	0.131	6.931
	2011-2016	0.459	3.714	1.927	-11.30	0.748	11.01

The total sample of treated pixels in the strict restriction level is 14,555 and 12,185 in the multi-use level. For low decentralization level the number of pixels is 3,748 and for high decentralization is 22,992. The low capacity classification level has 6,270 pixels and high capacity has 20,470. The total control pixels remain at 133,705. Elevation, slope, distances to the nearest PA border, roads, municipality capital and national capital were the covariates used for matching; the covariates listed in Table 2.5 did not pass Cochran's rule of thumb after matching because the maximum standardized difference in means is outside the 10% to 25% range.

Table 2.5. Pixel data for each PA classification and level.

Classification	Level	Treatment pixels	Failed Cochran's rule
Restriction	Strict	14,555	Dist PA, Dist Road
	Multi-use	12,185	Dist PA
Decentralization	Low	3,748	None
	High	22,992	Dist PA
Capacity	Low	6,270	Dist Mcap
	High	20,470	Dist PA

After PSM using the level of restriction we found that strict PAs had a positive and statistically significant impact on aNDVI for the 30-year period (1986-2016) and during 1986-1991, 1996-2001, 2001-2003 (Table 2.6). However, the ATT is statistically significant and negative during 1991-1996, 2003-2011, and 2011-2016, indicating that there was more loss in greenness within strict PAs versus similar areas outside strict PAs. Multi-use PAs show a different pattern and their impact on aNDVI outcome is not statistically significant for the 30-year period; the ATT is negative and statistically significant between 1991-1996, 2001-2003, and 2003-2011 indicating lower greenness within these PAs versus outside PAs (Table 2.3).

Low decentralized PAs show significant positive impact over the entire period and in all smaller time periods except 1991-1996 and 2011-2016 when the ATT is negative and significant. While these PAs have a positive effect on increasing greenness, the pixels show a trend in greenness reduction starting in 2001 and show a negative impact on aNDVI from protection starting in 2011. The ATT for PAs with high decentralization is not statistically significant for the 30-year period. These PAs increase greenness levels in 1986-1991, 1996-2001, and 2011-2016 as their impact is positive and significant, but for the other three periods high decentralization have on average a negative and significant impact on greenness.

Table 2.6. Estimated impact of PA on aNDVI outcomes per class level and period.

Class Level	Effect	1986-2016	1986-1991	1991-1996	1996-2001	2001-2003	2003-2011	2011-2016
Strict	ATT	0.065**	0.508***	-0.594***	0.269***	1.514***	-0.14***	-0.173***
		(0.006)	(0.027)	(0.027)	(0.026)	(.070)	(0.018)	(0.028)
Multi-use	ATT	-0.007	0.025	-0.084***	0.055**	-0.343***	-0.087***	0.236***
		(0.006)	(0.028)	(0.025)	(0.026)	(0.062)	(0.017)	(.027)
Low-D	ATT	0.266***	1.335***	-1.464***	0.395***	4.112***	0.137***	-0.534***
		(.012)	(.054)	(.060)	(.046)	(0.142)	(.044)	(.066)
High-D	ATT	0.002	0.158***	-0.159***	0.131***	-0.164***	-0.216***	0.294***
		(0.005)	(0.025)	(0.023)	(0.024)	(0.054)	(0.015)	(0.024)
Low-C	ATT	-0.034***	-0.055	-0.251***	0.329***	-2.412***	0.12***	0.54***
		(0.011)	(0.051)	(0.047)	(0.043)	(0.119)	(0.032)	(0.05)
High-C	ATT	0.072***	0.496***	-0.412***	0.181***	1.472***	-0.212***	-0.076***
		(0.005)	(0.023)	(0.024)	(0.022)	(0.053)	(0.014)	(0.025)

Robust Standard errors in (). * p<0.1; ** p<0.05; *** p<0.01.

Low capacity PAs have a negative and significant ATT over the full period and for 1986-2016, 1986-1991 and 1991-1996, and 2001-2003. Thus, low capacity PAs were losing greenness in those periods compared to similar areas outside PAs. As of 2003, however, low capacity PAs show a positive and significant impact on greenness. High capacity PAs show a significant and positive impact for the 30-year outcome period, and for 1986-1991, 1996-2001, and 2001-2003. Their ATT is negative and significant in 1991-1996, 2003-2011, and 2011-2016 which means greenness is reduced in those periods.

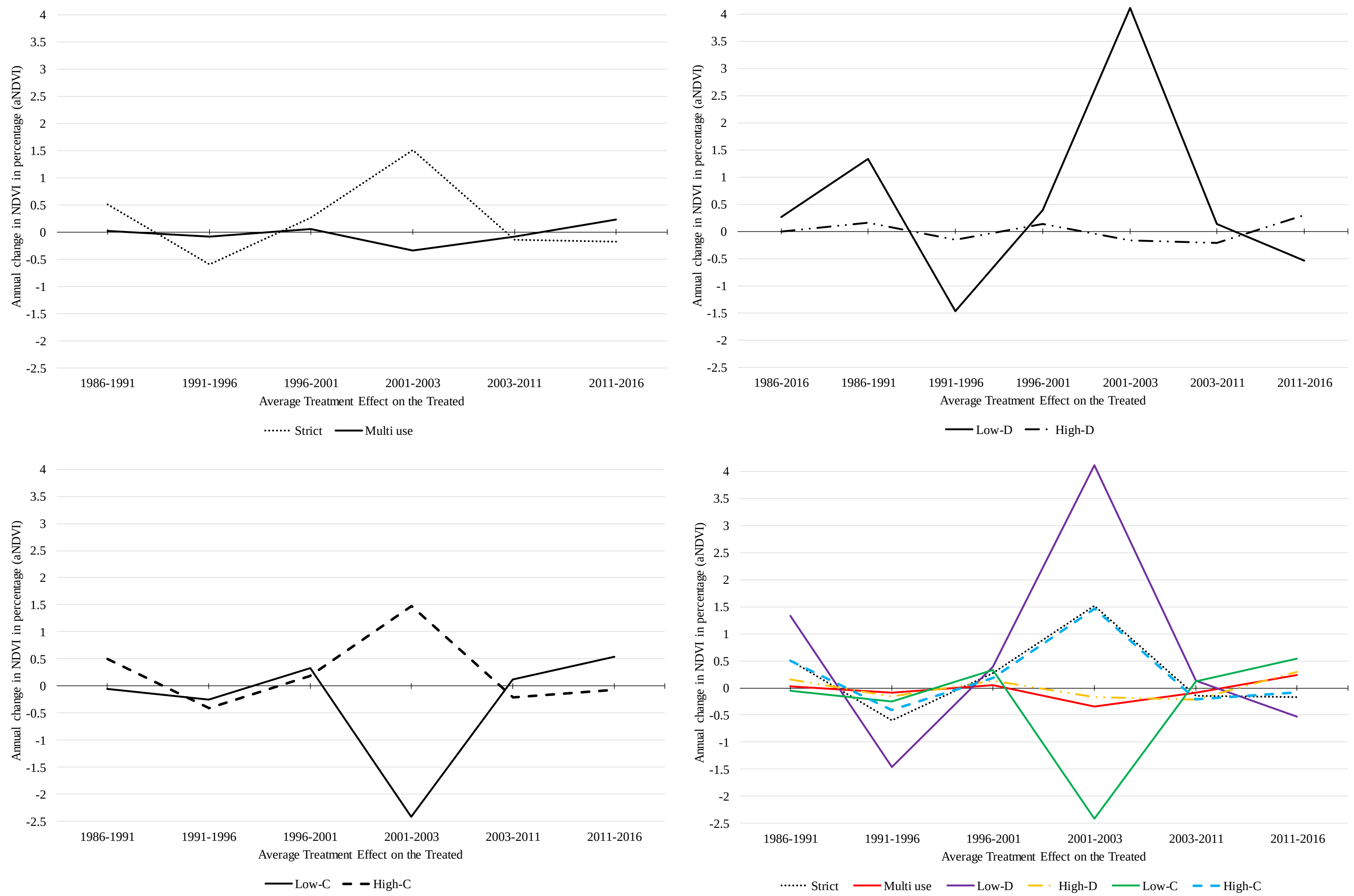

Figure 2.3. Average treatment effect on the treated per class level and period.

The temporal results for each classification and level after implementing the matching strategy are presented in graphs in Figure 2.3. The full matching regression analysis results for the period 1986-2016 is summarized in Table 2.7. The regression results indicate that with exception of low capacity PAs, the effect of most covariates is statistically significant; however, the sign and magnitude vary considerably across PA sub-groups. Regression results not provided here for other outcome periods show similarity in the variability of the effect from covariates. The results show a reduction in aNDVI as elevation increases for PAs classified as strict, highly decentralized, and with high capacity, but aNDVI increase with elevation in multi-use, low decentralization, and low capacity PAs. Slope and distance to national capital in most cases show a positive and significant effects on aNDVI—PA pixels with steeper slope and further from capitals tend to increase greenness.

Table 2.7. Regression on key covariates PAs classifications for 1986-2016 on aNDVI.

1986-2016	Elevation	Slope	Dist PA	Dist Road	Dist Mcap	Dist Ccap	cons
Strict	-0.0001***	0.001***	0.0015	0.00001***	0.004***	0.001***	0.174
	(0.00001)	(0.0002)	(0.002)	(0.000002)	(0.001)	(0.0001)	(0.02)
Multi-use	0.00005***	0.0007***	0.0094***	-0.000001	0.0004	0.002***	-0.09
	(0.00002)	(0.0002)	(0.002)	(0.000003)	(0.0009)	(0.0001)	(0.02)
Low-D	0.0001**	-0.003***	-0.069***	0.00004***	-0.001	-0.021***	1.913
	(0.00002)	(0.0005)	(0.006)	(0.000005)	(0.003)	(0.001)	(0.11)
High-D	-0.0001***	0.001***	0.009***	0.000001	0.003***	0.002***	0.049
	(0.00001)	(0.0002)	(0.002)	(0.000002)	(0.001)	(0.0001)	(0.02)
Low-C	0.0002***	0.0005	-0.002	-0.00001	0.003	-0.0002	-0.11
	(0.00003)	(0.0004)	(0.01)	(0.00001)	(0.003)	(0.0003)	(0.03)
High-C	-0.0001***	0.001***	0.00004	0.000005***	0.003***	0.001***	0.15
	(0.00001)	(0.0002)	(0.002)	(0.000002)	(0.001)	(0.0001)	(0.02)

Robust standard errors in (). * $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Discussion

The IE of PAs conducted for this study combines quantitative and qualitative data in a quasi-experimental design to create treatment groups of protected and unprotected spaces. The approach is an evaluation of the ATT on aNDVI and regression on observable drivers that affect patterns of annual change from 1986 to 2016. While effectiveness in avoiding LCLUC from protection is not guaranteed by any form of PA governance structure (Nolte, Agrawal, Silvius, et al., 2013), in addition to exploring how impact on outcomes changes across PAs by level of restriction, this study contributes to filling the knowledge gap by assessing the variation in PA impact with changes in levels of decentralization and management capacity applied to the Trifinio Region.

The estimates of ATT in strict versus multi-use restriction levels of PAs are quite different (Table 2.6). Strict PAs show a positive trend in most time periods but have negative effect with a -0.6% reduction in vegetation between 1991-1996, and their effect is negative in the last period 2011-2016. The impact of multi-use areas is less erratic with small positive and negative fluctuations around zero across periods—the ATT is not significant for the 30-year period and 1986-1991, and the highest positive and significant effect (0.2%) is for 2011-2016. On average, strict PAs appear to have had a much larger positive impact than multiple-use PAs on changes in greenness. A possible causal explanation is that multiple-use PAs are on average located at lower elevations, closer to roads, and closer to markets compared to strict PAs—in matching regression, elevation is the factor with strongest statistically significant effect and has a positive correlation with increased aNDVI (Table 2.7). This indicates that access to land in and around multi-use PAs is correlated with land uses that show low NDVI which replace vegetation that would show high NDVI values—for example, agricultural activities that typically show low levels of NDVI vs forest. While some studies in Latin America suggest that multiple-use PAs have been more effective in stemming deforestation (Blackman et al., 2015; Nelson & Chomitz, 2011), other studies in Brazil show that strict PAs consistently avoided more deforestation than sustainable use areas (Nolte, Agrawal, Silvius, et al., 2013), and a study in European Russia found that strict PAs reduced forest disturbance by 1 to 2 percentage points compared to multi-use PAs (Wendland et al., 2015).

Highly decentralized PAs also show small positive and negative ATT fluctuations around zero across outcome periods, with an insignificant impact for the 30-year period and a positive impact that increase greenness at a 0.29% change in 2011-2016 period. Low decentralized PAs increased greenness during the 30-year period at a 0.26% rate—greenness in these PAs increased in four periods with a highest change of 4.11% in 2001-2003, but the

ATT shows a reduction in greenness of -1.46% in 1991-1996 and -0.053% in 2011-2016. On average, high decentralized PAs show a much smaller impact than low decentralized PAs on changes in greenness. Seven high decentralization PAs are classified as multi-use and the other five are strict—this overlap is likely the reason multi-use and high decentralization PAs show small impact in greenness in the study (Figure 2.3). Elevation and distance to roads are driving factors that explain these differences in outcomes among PAs decentralization levels. The average elevation for low decentralized PAs is 966 m and distance to roads is 2.25 km, and for high decentralized PAs the averages are 1777 m and 2.77 km respectively. Matching regression results for the 30-year period show a positive and significant correlation between elevation, distance to roads, and low decentralization with aNDVI, whereas high decentralization PAs have a negative and significant correlation between elevation and aNDVI but insignificant between distance to roads and aNDVI (Table 2.7). This means that greenness decreases at higher elevation.

High capacity PAs have a positive and significant impact for the 30-year period with a positive and significant ATT from 1986 until 2001 that increased aNDVI at 0.07%. Low capacity PAs show the reverse trends for these same periods and reduced greenness at -0.03%. This trend started to reverse in 1991 and for the period 1996-2001 low capacity PAs have a positive impact. The magnitude of impact is lower for low capacity PAs and the largest negative aNDVI for all periods is -2.4% in 2001-2003; in the matching regression, elevation, distance to roads, and markets show a negative effect for both low and high capacity PAs in 2001-2003. For the 2011-2016 regression, elevation, distance to roads and markets show a positive effect with high capacity PAs and for low capacity it is the opposite save for elevation. The results from the matching regression suggest that on average low capacity PAs show little impact due to their location at lower elevation, closer to roads, and closer to markets compared to high capacity PAs which exposed them to threats and activities that reduce vegetation (e.g., deforestation, fires) or designate them to drier habitats. Capacity is negatively correlated with PA size which indicate that smaller PAs have less funding, staff and equipment which constrains their ability for monitoring and regulation enforcement.

Recently, the performance of IE of the effectiveness of conservation approaches has become an important source of information with increasing research in this area (Blackman, 2013; Pattanayak, Wunder, & Ferraro, 2010) decision-making. In addition to the traditional evaluation of PAs in relation to restriction levels, our study in the Trifinio Region includes factors to inform our understanding of how governance structures affect PA effectiveness in maintaining vegetation by combining quantitative and qualitative data in a quasi-experimental design (Blackman, 2013; Ferraro, 2009; Jones & Lewis, 2015; Macura et al., 2013, 2015). Our variations in findings show that the relation between governance and PA outcomes is very complex. Part of the challenge in detecting the effects of governance on PA outcomes relates to high probability of detecting little impact because of the history of high deforestation in Central America and in the Trifinio countries (Figure 2.1).

There appear to be two broad PA classifications— (1) multi-use, high decentralized, low capacity PAs and (2) strict, low decentralized, and high capacity PAs, which follow similar pattern in outcome across time (Figure 2.3). Strict, low decentralization, and high capacity PAs show the greatest positive and significant effect on an increase in greenness, whereas multi-use, high decentralization, and low capacity PAs show the greatest negative and significant effect with a reduction in aNDVI. Future analysis that splits the dataset using these two broad classifications may yield new insights to detect the contributions from governance to PA effectiveness. Also, future analysis could explore how PA capacity interacts or moderates PA effectiveness in relation to management restriction and decentralization levels. Further studies are needed to assess these interactions with data from key informants on what motivates decentralization and leads to capacity in some PAs and not others.

The heterogeneity in our findings on the impact from variations of PA treatments on vegetation greenness are possible limited by unobserved confounding factors that affect the probability of allocation of pixels into the treatment groups. Pressure on land use change is driven by confounding factors—that affect both the treatment and the outcome (Ferraro & Hanauer, 2015)—like past land tenure, agroforestry farming systems, or beef and coffee prices (Schlesinger et al., 2016). For example, we lack baseline data on the characteristics of pixels before 1986 which limits options such as using the differences-in-differences estimator—i.e., estimating the difference in average outcomes before and after the protection designation is not possible for PAs in Trifinio. Also, we lack data on key drivers of change like coffee prices or beef, soil quality, and water availability that affect land cover change and vegetation types. Similarly, we lack historical data important for better understanding how the governance process unfolds in PAs in the region—the variables used to create the decentralization and capacity classes may not be sufficient to capture the complexity of the relationship between PA designation and changes to these metrics over time. If some of these unobserved variables are correlated both with designation of a protected site and the outcome, the ATT could be under or over estimated.

The high variation in ATT across epochs, between the type of PA treatment (e.g., restriction vs decentralization), and between levels within a type of treatment (e.g., strict vs multi-use levels within the restriction type of treatment), is to a large extent related to the nonrandom allocation of PAs and the nonrandom allocation PA treatment type. For example, multi-use PAs are by designation more likely to be exposed to short term and more dynamic changes in LCLUC, most of these PAs are also highly decentralized and low capacity. As such, with higher exposure to changes in vegetation from pressures on land uses, it is expected there will be a negative impact on aNDVI with a tendency towards low values in greenness. Furthermore, governance processes in Trifinio require radical policy reinforcement with more support for stakeholders participating in PA decentralization and development management capacity for PAs in general.

Finally, we may have measurement error in our dependent variable. Mapping vegetation using remotely sensed data of large hilly and rugged areas, complex tropical ecosystems, or areas that are seasonally dry is a challenging task, a problem further aggravated by spatially differential rates of leaf loss and leaf conditions based on eco-climatic, topographic and soil differences (Krishnaswamy, Kiran, & Ganeshaiah, 2004). Another challenge is to distinguish between human driven land cover change and inter-annual variability of ecosystems at the regional scale—potentially susceptible to global change or regional change like alternating El Niño (warm) and La Niña (cool) events (Bradley & Mustard, 2008). These challenges associated to NDVI can cause measurement errors because changes in rain patterns affect vegetation greenness but these errors in NDVI measures are unlikely to be correlated with variation in treatment (Alix-Garcia, McIntosh, Welch, & Sims, 2013). The high variation in outcomes across periods in Trifinio can be explained by the susceptibility of NDVI to climate events such El Niño, especially for the months we took measurements. Also, dramatic changes in impact (e.g., from 1996-2001 to 2001-2003) may be due to vegetation loss probably caused by deforestation driven by socioeconomic forces (e.g., changes in coffee prices), El Niño effect, and other factors. Additional data is needed to understand how these probable causes interact with PAs. El Niño occurring around Christmas in the tropical Pacific is known to cause prolonged dry weather that severely reduced agricultural outputs in 2015 for El Salvador, Guatemala, Honduras and Nicaragua (FAO, 2015). The effects of La Niña in Central America are typically heavy rainfall, landslides, and floods (Baker & Haggar, 2007). Based on historical data years of El Niño has caused a moderated effect during most outcome periods to very strong in years between 1996-2001 and 2011-2016, and La Niña effect has been mainly weak with a strong effect in years between 1986-1991 (Diaz & Markgraf, 2000; NOAA, 2015).

Conclusion

Rigorous IE studies about the impact of PAs are helping to inform future policy decisions in terms of PA designation by type and categorization. However, current IE of PAs are limited in that they do not incorporate key aspects related to governance and management capacity, factors which may serve as causal explanations for observed PA outcomes. In this work we have incorporated governance aspects into assessment of PA impacts on LCLUC and these factors help elucidate the effects found. More attention to the role of governance and management capacity for PAs would enhance global plans to implement additional PAs to halt the loss of biodiversity and ecosystem services. Just as the nonrandom allocation of PAs is one fundamental justification to conduct an IE, the reasons behind PA designation into a management category, or the underlying process that lead to decentralization and allocation of resources to increase capacity are nonrandom decisions that need to be controlled for more carefully when estimating the impact of PAs on LCLUC outcomes.

The Trifinio Region is a rich case to assess the effect of governance characteristics on conservation outcomes in an IE that brings additional needed information into assessing why and whether PAs are effective in addition to focusing on how restriction affects outcomes. The results found here do not show clear patterns, and indeed governance itself is a messy process. The effect of governance on PAs is likely non-linear and will take additional qualitative and quantitative study to fully understand it. We find that restriction in resource use does not automatically determine positive outcomes as the impact can radically change from one period to another. This is similar for highly centralized PAs. Capacity has the clearest effect on PA outcomes and future research will explore its interactions with restrictions and decentralization. Building capacity to enable managers with the working tools to increase PA effectiveness may be the clearest target area for the conservation community to improve PA outcomes.

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Chapter 3 Do Transboundary Conservation Areas Impact Land Cover Outcomes? An Evaluation of Protected Areas in the Trifinio Region

Abstract

When conservation takes place across borders it is important to consider the outcomes on land cover and land use change (LCLUC) from a transboundary perspective. International efforts to enhance this perspective include the creation of transboundary areas and transboundary protected areas (PAs) also known as TBPAs. Some of the most important benefits of transboundary conservation relate to the protection and maintenance of biodiversity at spatial scales beyond national borders, connectivity, and cross-border management cooperation. Despite an increase in rigorous assessment of the effectiveness of PAs, there are no existing impact evaluations of PAs within transboundary sites on LCLUC. We assess transboundary PA effectiveness by estimating the impact of 15 PAs on changes in Normalized Difference Vegetation Index (NDVI) over a 30-year period and compare LCLUC outcomes by two levels of PA restriction and across three countries in the Trifinio Region, Central America. We estimate the impact of 11 PAs located within a buffer outside Trifinio and compare their effectiveness by restriction, across countries outside Trifinio, and inside the Region to tests whether the transboundary designation of Trifinio has changed PA effectiveness. We integrate remote sensing and spatial econometrics to estimate the average treatment effect of PAs across space and time using quasi-experimental methods of matching. Overall, PAs inside Trifinio have had a larger impact on NDVI than PAs outside the transboundary area. There is, however, variation across PA types, with strict PAs inside Trifinio having an effect on greenness but no effect of multi-use PAs. Outside Trifinio strict PAs have no statistical effect on greenness and multi-use PAs have a statistically significant and negative impact. There is considerable variation in impact across the three countries inside and outside of Trifinio. These differences shed light on drivers of change operating within and across countries and how the transboundary designation of Trifinio is affecting LCLUC. Findings from this study advance theory on cross-country and TBPAs effectiveness and rigorous impact evaluation of PAs. Understanding the relationship between transboundary conservation designation and effectiveness is fundamental to assessing the theoretical assumptions around how these conservation approaches affect drivers of LCLUC at regional and sub-regional scales.

Introduction

Governance structures have important impacts on land cover and land use change (LCLUC) and natural resource management (Lemos & Agrawal, 2006). For example, major political events, associated policy interventions, and financing efforts are underlying causes that affect land management and local land use processes. Given the transnational nature of environmental issues and their linkage to numerous actors across global, regional, national, and local levels, transnational environmental concerns are best understood through the lens of global environmental governance. Duffy (2005) proposes that transboundary governance challenges not only include attempts to manage particular interests and issues by formal and informal institutions and regimes, but also include institution building, empowerment, and setting up a working system to solve the transnational issues of interest. Considering the relationship between LCLUC and conservation approaches from an environmental governance perspective is instrumental for theory development for our understanding of coupled human-ecological systems, especially when decision-making and collective actions spans multiple borders.

The theoretical aspects of LCLUC focus on detecting changes on the landscape and their causal explanations. This requires a clear understanding of the concepts of land cover (the characteristics of the land surface) and land use (the reasons to use the land cover) (Angelsen & Kaimowitz, 1999; Lambin & Geist, 2006). As a process, LCLUC responds to multiple agents, political, social and historical context, climatic and ecological changes, and its effects and causes are manifested at multiple spatial and temporal scales (Lambin & Geist, 2006; Lambin et al., 2001; Meyfroidt, Lambin, Erb, & Hertel, 2013; Turner, Lambin, & Reenberg, 2007; Young et al., 2006). The drivers of LCLUC are classified as underlying causes and proximate causes. The underlying causes of LCLUC are indirect drivers, or the fundamental aspects that reinforce the more proximate causes, which may be activated at the local or regional levels or at a global scale. The proximate causes include direct or physical actions on land cover (e.g., agriculture, livestock, forestry, land protection, infrastructure construction, etc.), which operate at the local level (e.g., individuals, farms, households, communities, etc.) (Lambin & Geist, 2006). An understudied area of research related to land use change is exploring biophysical and socioeconomic drivers and impacts of governance on LCLUC. This involves evaluating conservation policy impacts by analyzing the interactions between an intervention (e.g., creation of protected areas (PA) and other conservation measures) and socioeconomic outcomes (Lambin et al., 2014), and is also related to understanding the theory of change behind a land use driver, or the root of the causes of how change unfolds (Taplin & Clark, 2012).

PAs are one important outcome of governance processes and a prominent conservation approach used throughout the world and in Central America to minimize the degradation of natural resources from land use change. In the context of conservation across political borders, a common practice is the creation of transboundary PAs also known as TBPAs or Peace Parks. A TBPA extends across boundaries between "states, sub-national units… autonomous areas and/or areas beyond the limits of national sovereignty or jurisdiction… dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed co-operatively through legal or other effective means" (Sandwith, Shine, Hamilton, & Sheppard, 2001, p. 3). The creation of TBPAs has been done by governments ratifying agreements that create bilateral or trilateral organizations to foster cooperation, collaboration, and policy making for transboundary conservation (Stoett & Temby, 2015). The growth in numbers of TBPAs around the world has increased from 59 in 1988 to 169 in 2001 and an estimated 227 in 2007, containing 666 individual PAs in 113 countries (McCallum & Schoon, 2011; Zbicz, 2001).

While TBPAs have existed since 1924 it was not until recently, in the late 1990s and early 2000s, that attempts were made to harmonize their terminology; common terms include 'transfrontier PAs', 'transboundary natural resource management areas', 'peace parks', 'parks for peace', 'transfrontier conservation areas' (Lysenko, Besançon, & Savy, 2007; McCallum & Schoon, 2011). For example, Waterton (1895) and Glacier (1910) National Parks, in Alberta, Canada and Montana, USA are commonly considered the first international transboundary parks, and were also jointly designated the first international peace park in 1932 (Slocombe & Danby, 2006). Examples of TBPAs are numerous in all continents, for example, the Three-Nations Namib Desert trans-frontier conservation areas spanning the borders of South Africa, Namibia and Angola; the four countries of the lower Mekong River Region—Cambodia, Lao PDR, Thailand and Vietnam; La Amistad International Park shared by Costa Rica and Panama; West Tien Shan Biodiversity Conservation Project in Uzbekistan, Kazakhstan and the Krygyz Republic; and the Great Lakes Region of Africa involving Burundi, Democratic Republic of Congo, and Rwanda (ICEM, 2003; Sand, 2014; Slocombe & Danby, 2006). Both the International Union for Conservation of Nature (IUCN) and the International Tropical Timber Organization (ITTO) have taken the initiative to work on creating a comprehensive terminology which group four types of transboundary conservation practices: TBPAs, Parks for Peace, Transboundary Conservation and Development Areas, and Transboundary Migratory Corridors. These categories will be referred to as TBPAs for the remainder of the paper.

Some of the most important benefits of transboundary areas and TBPAs relate to the protection and maintenance of biological diversity at spatial scales beyond national borders, connectivity, and cross-border management cooperation. These notions imply that with an enlarged core site there is more availability of undisturbed habitat, native vegetation, and larger ecological niches for more species. They are also more likely to encompass entire ecological processes and functions, such as water regulation, which do not adhere to political borders. Furthermore, transboundary joint management operations reduce costs, redundancy in monitoring, and maximize human capital productivity. TBPAs also provide opportunities for political cooperation by increasing trust among countries, reinforcing confidence, and extending cultural bounds (McCallum & Schoon, 2011).

Conducting rigorous studies to measure how PAs or TBPAs reduce deforestation is important to assess their effect on conservation outcomes. However, if not done properly, evaluating PAs can lead to biased results because PAs and TBPAs are not randomly assigned and protection may increase deforestation in unprotected sites (i.e., the spillovers or displacement effect). In order to rigorously assess whether there is an impact of PAs on outcomes requires counterfactual impact evaluation methods (Ferraro and Pattanayak 2006). For example, Andam et al. (2008) used matching methods for evaluation and found that approximately 10% of forests in PAs would have been cleared without protection as opposed to estimates that did not account for the non-random location of PAs which found that PAs led to about 65% in deforestation reduction. Blackman (2015) used nonparametric matching combined with parametric regression to control for lack of randomness of PA sites and effectiveness. Blackman's study was conducted in the Maya Biosphere Reserve in Guatemala and estimated the relative effectiveness of the core PA and various management regimes within the multiple-use zone. He found that mixed-use protection has been more effective in reducing deforestation than strict protection, specifically due to the performance of forest concessions located within the multiple-use zone that ensure sustainable forest uses and local community benefits; some other studies have found similar results about multiple-use PAs avoiding more deforestation than strict PAs (Blackman et al., 2015).

While a growing number of studies employ counterfactual impact evaluation methods to measure the impacts of PAs within one country (Andam et al., 2008; Andam et al., 2010; Wendland et al., 2015), there are none that we know of that compare the impacts of PAs across multiple country borders or measure the impact of transboundary conservation designations on conservation outcomes. The purpose of this study is to analyze the impact of the transboundary Trifinio Region of Central America on LCLUC outcomes between 1986 and 2016. The Trifinio Region spans Guatemala, Honduras, and El Salvador and includes 15 PAs, including one TBPA. Our first objective is to estimate the impact of these 15 PAs on changes in Normalized Difference Vegetation Index (NDVI) and to compare effectiveness of PAs across the three countries. The purpose of this objective is to assess whether transboundary effectiveness is similar across the three countries. Our second objective is to estimate the impact of 11 PAs located within a 20-km buffer just outside the Trifinio Region and compare their effectiveness to PAs inside the transboundary area. This objective tests whether the designation of Trifinio has changed the relative effectiveness of PAs within the same country.

We integrate remote sensing and spatial econometrics to estimate the impact of PAs in this transboundary region. We estimate the average treatment effect of PAs across space and time using quasi-experimental methods of matching—i.e., a counterfactual approach for comparing the current condition with what would have occurred in the absence of the intervention (Blackman, 2013; Ferraro, 2009; Jones & Lewis, 2015). The outcome variable is NDVI converted to percentage annual change from 1986 to 2016. Findings from this study advance theory on cross-country and TBPAs effectiveness and rigorous impact evaluation of PAs. Understanding the relationship between transboundary conservation designation and effectiveness is fundamental to assess the theoretical assumptions around how these conservation approaches affect drivers of land use change at regional and sub-regional scales.

Methods

Transboundary Conservation in the Trifinio Region

The Trifinio Region is a political administrative unit with an area of nearly 750,000 ha that resulted after a 1987 peace agreement in Central America (Figure 3.1). During the 1980s (and even before this decade) most countries in CA went through an agonizing period of civil wars and political turmoil. The region became a strategic political target between global powers from the West and the East, represented by the United States and the former Soviet Union (Paige, 1998). These wars had tremendous negative implication on economic development and institutional reforms. The wars also affected LCLUC and the use of natural resources in ways that are not clearly understood even today. This period of deep suffering, particularly for civilians in the region, started to wane with a process of democratization that was formalized with the signature of the Peace Accords by the five Central American Presidents on August 7, 1987. As an outcome of the peace process the governments of El Salvador, Guatemala and Honduras established the Trifinio Region through an international agreement known as the “Plan Trifinio” ratified in March 1998, May 1998, and July 1999 by the Congress of each country respectively (OAS, 1993).

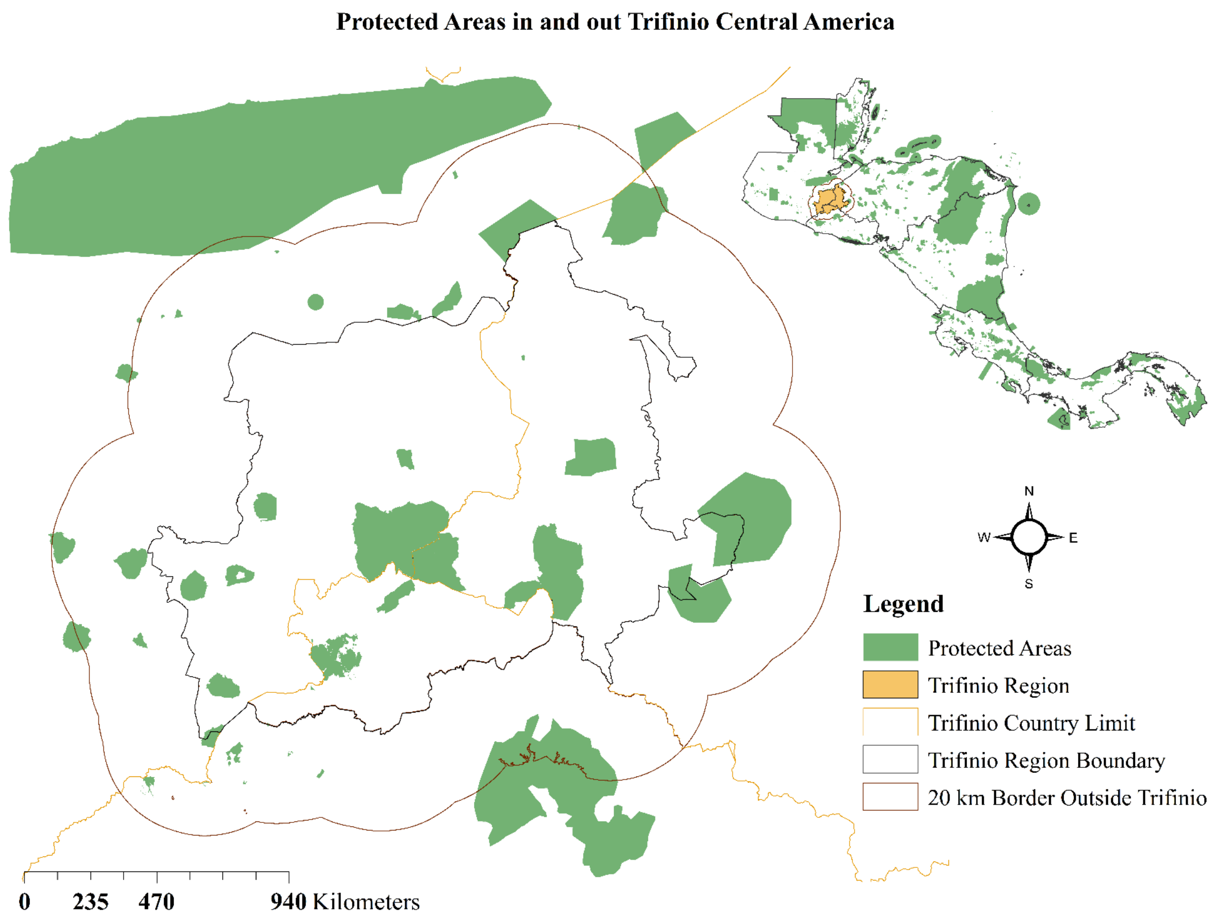

Figure 3.1. Protected areas in Central America, in Trifinio, and in a 20-km buffer.

An additional outcome of the peace process took place on November 21, 1987, when the Vice-presidents of El Salvador and Guatemala, and President-elect of Honduras, signed a declaration that established the Trifinio Fraternidad International Reserve of the Biosphere to promote the conservation and sustainable use of natural resources as well as the protection of each country's historical and cultural heritages (MARN, 2010); this decision is formally reflected in the governance of the Plan Trifinio. Along with its core protected sites of nearly 14,425 ha located in the Montecristo massif where these neighboring countries share borderlines, the Trifinio-Fraternidad International Reserve of the Biosphere includes a large area of cloud forest, a buffer zone, and an area of multiple-use land. In 2011 the Trifinio-Fraternidad Biosphere Reserve became part of the UNESCO-MAB system, the first tri-national biosphere reserve in Central America (UNESCO, 2011). This Biosphere Reserve covers an area of 22,100 ha and is considered an example of international cooperation for environmental protection and local sustainable development. The Biosphere Reserve has different names in the different countries: Trifinio Biosphere Reserve in Guatemala, Montecristo Trifinio National Park in Honduras, and Montecristo National Park in El Salvador. This TBPA harbors critical water resources that provide drinking water to nearly three million people living in communities located in the Motagua, Ulúa, and Lempa watersheds; the latter being the largest in the region and crosses the three countries before draining into the Pacific Ocean (Artiga, 2003; UNESCO, 2011). Due to this tri-national cooperation, Trifinio provides an interesting case study in which to assess the impacts of transboundary conservation on LCLUC due to the social, economic, and political complexities across political-administrative units and national boundaries.

This study centers on 15 PAs located within Trifinio and 11 PAs that are just outside Trifinio—a description of all PAs is provided in Table 3.1. We defined a 20-km boundary around the Trifinio border and randomly selected PAs in this boundary. The smallest PA is less than 15 ha and the largest is 26,266 ha. The oldest PAs were established in 1956 and the newest in 2010. Most PAs outside Trifinio are still pending formal legalization but were proposed as PAs in 1994; one PA in Guatemala was managed by a local municipality until 2015/2016 when it was declared private land.

Table 3.1. Summary of Protected Area Characteristics.

ID	PA Name	Declared Year	Area in Ha	Management Category	IUCN Equivalent	Restriction Level
			Guatemala			
1	Volcán Ixtepeque*	1956	1,659.58	Permanent Closure Zone	(IV)	Multi-use
2	Volcán Las Víboras	1956	2,144.22	Permanent Closure Zone	(IV)	Multi-use
3	Volcán Quezaltepeque	1956	332.00	Permanent Closure Zone	(IV)	Multi-use
4	Volcán Suchitán	1956	2,539.26	Regional Park and Natural Recreation Area	IV	Multi-use
5	Reserva de la Biosfera Trifinio-Fraternidad	1987	4,000.00	Biosphere Reserve	V	Multi-use
6	Volcán y Laguna de Ipala	1998	2,012.50	Multiple Use Regional Park	III	Multi-use
7	Parque Regional Municipal La Unión**	2007	3,267.00	Regional Municipal Park	IV	Multi-use
			Honduras			
8	Refugio de Vida Silvestre Erapuca	1987	6,522.00	Wildlife Refuge	(IV)	Multi-use
9	Parque Nacional Montaña Celaque*	1987	26,268.00	National Park	II	Strict
10	Parque Nacional Montecristo Trifinio	1987	8,270.00	National Park	II	Strict
11	Reserva Biológica El Guisayote	1987	14,081.00	Biological Reserve	(II)	Strict
12	Reserva Biológica El Pital	1987	2,700.00	Biological Reserve	(II)	Strict
13	Reserva Biológica Volcán Pacayita*	1987	10,249.00	Biological Reserve	II	Strict
14	Montaña Celaque	1987	26,266.00	National Park	II	Strict
15	Cerro Azul	1987	12,083.00	National Park	II	Strict
16	Volcán Pacayita	1987	10,249.00	Biological Reserve	(II)	Strict
			El Salvador			
17	Parque Nacional Montecristo	1986	2,154.16	National Park	(II)	Strict
18	Paraje Galán*	2007	24.35	Mixed Use Zone/Area	(IV)	Multi-use
19	Parque Nacional San Diego, San Felipe, La Barra	2007	1,916.00	National Park	(II)	Strict
20	Rancho Grande o El Junquillo**	1994	402.00	Natural Area	(III or VI)	Multi-use
21	Las Tablas**	1994	28.00	Natural Area	(III or VI)	Multi-use
22	San José Los Amates**	1994	27.00	Natural Area	(III or VI)	Multi-use
23	San Jerónimo**	1994	39.00	Natural Area	(III or VI)	Multi-use
24	La Magdalena**	1994	726.00	Natural Area	(III or VI)	Multi-use
25	Tahuapa**	2010	15.00	Natural PA	(III or VI)	Multi-use
26	El Chaparrón o San Cayetano**	1994	127.00	Natural Area	(III or VI)	Multi-use

Notes: * Denotes PA is only partially in Trifinio. ** Denotes PA outside Trifinio. For Not Reported PAs (Roman number possible equivalent).

Data Collection

Protected Area Classification

In addition to the World Database on Protected Areas (WDPA), we used shapefiles provided by SIGAP in Guatemala, ICF in Honduras, and MARN in El Salvador to create a GIS dataset for the selected PAs (Table 3.1). PAs are classified into two restriction levels—strict and multi-use—based on the IUCN system class reported in the WDPA and for unreported PAs an equivalent was assigned based on national legislation (IUCN & UNEP-WCMC, 2016). PAs in IUCN categories I and II are mainly created for science, wilderness protection, ecosystem protection, and recreation, and are in the “strict” restriction level, and PAs in IUCN categories III to IV are established largely for conservation of specific natural features, sustainable use of natural resources, or require management intervention and are in the “multi-use” restriction level. A national management category may change in the three countries but their categorization is standardized to IUCN categories based on the national categories descriptions on use restrictions. There are about 50% strict and 50% multi-use PAs in our study area (Table 3.1).

Remotely sensed data

Medium resolution remotely sensed Landsat images for Trifinio were acquired from the USGS Earth Resources and Observation Science Center (USGS/EROS) as surface reflectance values to develop least-cloud, approximately five-year, epochs of vegetation index-based greenness-based land cover and land use (GLCLU) data. The GLCLU data are being used as a proxy to measure the extent of forest transition due to the spectral confusion in coffee and agroforestry systems. The area of Trifinio geographically comprises a single Landsat scene (World Reference System (WRS) Path/Row 19/50) per epoch. The source data had already been orthocorrected to the most accurate geometric and topographic level (L1T), radiometrically and atmospherically corrected via the Landsat Ecosystem Disturbance Adaptive Processing System (Masek et al., 2013) and processed to a cloud-shadow Fmask (Zhu & Woodcock, 2012) through the USGS/EROS Science Processing Architecture Climate Data Record (CDR) program (USGS, 2016). Fmask data were re-classed to Boolean layers—for USGS/EROS these are provisional data because the code is subject to change.

The cloud and shadow Fmask Boolean layers were used to mask out the compromised image sectors from all processing and analyses streams. After cloud masking, all raster images and vector data files were resampled to a common raster grid using the Universal Transverse Mercator (UTM) Zone 16N using the WGS1984 datum, while maintaining the original Landsat resolution of 30 meters, using remotely sensed image processing tools (ArcGIS, v. 10.3; ENVI "ENvironment for Visualizing *Images" v. 5.3.1*; and TerrSet v.18.21; TerrSet's SAMPLE.exe).

NDVI layers were prepared to create ranked greenness in quintile-based categories (Rouse et al., 1973). When more than one image made up an epoch, least cloud images were formed by combining them into epochs using maximum NDVI value criteria. All NDVI data was collected between January and March which is a difficult time to assess green vegetation; however, this is the best time to minimize noise in the data as least cloud are only feasibly accessible during the deciduous leaf-off dry season (Annex B).

Regional climate events like hurricanes or El Niño/La Niña pose a difficult challenge to analyze changes in vegetation measured by NDVI between epochs. Using NDVI makes it difficult to distinguish between socioeconomic drivers in land cover change and natural changes in ecosystems in the landscape (Bradley & Mustard, 2008). Our NDVI measurements were taken in times that coincide with El Niño/La Niña phenomena which takes place around Christmas causing longer than average periods of dry weather or precipitation that severely reduced vegetation greenness (Baker & Haggar, 2007). In addition, several El Niño/La Niña years fall within our outcome epochs with dry moderated years during most of the 30-year period to moderate rain for the 30-year period (Diaz & Markgraf, 2000; NOAA, 2015). These challenges associated to NDVI can cause measurement errors because changes in rain patterns affect vegetation greenness but these errors in NDVI measures are unlikely to be correlated with variation in treatment (Alix-Garcia et al., 2013).

PA Sampling and Covariates

Only pixels that comply with the selection criteria of being free of clouds, shadows, and water bodies, and have no missing data across time and space, were sampled inside and outside PAs which generated two datasets to measure changes in greenness—one for inside and the other for outside Trifinio with protected or “treated” pixels and unprotected or “control” pixels. The inside Trifinio sample included just over 27,000 treated units and slightly more than 722,000 control units; and the outside Trifinio sample included nearly 34,000 protected units and over 959,000 controls. For PAs less than 50 ha, 50% of pixels, and for PAs larger than 50 ha, 10% of pixels, were randomly selected as treated units. Control pixels outside PAs were randomly sampled at 10%.

NDVI values were estimated for 1986 and 2016. Each NDVI pixel measure is used to calculate the annual change in percentage (aNDVI); aNDVI was calculated using the formula from Puyravaud (2003, p. 595) included in Annex A. Additional socioeconomic and geophysical land measures on elevation, slope, distance to roads, distance to PA boundary, and distance to municipality capitals, and distance to national capitals (Table 3.2) were generated in GIS. For outside of Trifinio we used the Central American Commission on Environment & Development (CCAD) database which has information for roads, municipalities, and their capitals—all these data were projected in Universal Transverse Mercator (UTM) Zone 17N and re-projected to UTM Zone 16 North. For elevation and slope we used data form the Shuttle RADAR Topography Mission v. 3.0 Global Land 1 Arc-Second (SRTMGL1) which came in Geographic Projection in the datum of WGS84 and was re-projected and extracted to align with the CCAD data.

Table 3.2. Variable description and unit of measure for pixel level relevant covariates.

Variable	Variable description
PA ID	PA identification number
Restrict	PA restriction levels; 0 = not PA, 1 = Strict use, 2= Multi-use
Elevation	Elevation in meters above sea level (masl) of a sample pixel
Slope	Percentage slope of a sample pixel
Distance to PA	Distance to the nearest PA border in meters
Distance to Road	Distance in km from the centroid of a pixel to the nearest road
Distance to Municipal Capital	Distance in km from the sample pixel to the municipality's capital
Distance to National Capital	Distance in km from the pixel to the national capital city
NDVI	NDVI value of the pixel between 1986 and 2016
aNDVI	Annual change in NDVI of a pixel in the 30-year outcome period in percentage

Data source: Authors' creation.

Data Analysis

We use matching as the quasi-experimental impact evaluation method to control for the non-random allocation of protection and to reduce observable bias in the estimated impacts. We use propensity score matching (PSM), generating a propensity score (PS) for protected and unprotected pixels conditioned on selected covariates (Table 3.2) that are believed to affect assignment to PA status and LCLUC outcomes. The PSs were estimated using a logit model specification. A matched sample was then created by matching treated and untreated units on the predicted PS using a caliper band of 0.2 times the standard deviation of the PS to eliminate approximately 99% of the bias due to the measured confounders and minimize the mean squared error of the estimated treatment effects Austin (2011). Pairs of treated and untreated pixels were matched in this study using 1:1 nearest neighbor matching. The quality of the match and covariate balance after matching were evaluated. After units in the comparison groups are matched, the unmatched comparison units are discarded and are not directly used in estimating the treatment impact (Dehejia & Wahba, 2002).

We report the impact in terms of Average Treatment Effect on the Treated (ATT) between treated pixels and control pixels. The ATE is the mean of the difference between treated units (Y_t) and control units (Y_0) that were not exposed to the treatment; $\tau_t = E(Y_t - Y_0)$. The ATT is conditional to only those units getting the treatment ATT = $E[Y_i (1) - Y_i (0) \mid T_i = 1]$; where T

= 0 indicate control pixels and T = 1 indicate treated pixels (Imbens & Wooldridge, 2009; Khandker et al., 2010). In addition, we used matching regression analysis with robust standard errors—where aNDVI for a given period is the dependent variable and the regression covariates are those listed in Table 2.2. All matching estimates were generated using Stata 14.2 commands psmatch2 version 4.0.11 and teffects psmatch.

The specific tests implemented using PSM were:

1. Impact of all PAs inside and outside Trifinio by restriction categories, i.e., strict and multi-use PAs.
2. Impact of PAs for each of the three countries and 15 PAs inside Trifinio.
3. Impact of PAs outside Trifinio in the 11 PAs in the 20-km buffer.

Results and Discussion

The total pixels sampled in this analysis inside Trifinio is 160,445 and outside Trifinio is 205,794 with 26,740 and 34,299 protected pixels respectively; these are the full set of pixels that were randomly selected from the raw dataset and comply with the selection criteria. Inside Trifinio nearly 23% of pixels are in Guatemala, 63% in Honduras, and 14% in El Salvador—these proportions are the same for protected and not protected pixels. For outside Trifinio the proportions of pixels by country, protected, and not protected pixels are 40%, 55%, and 5% for each country. The number of pixels in strict PAs in Trifinio is 14,555 and 12,185 in multi-use PAs. For outside Trifinio there are 28,693 strict PA pixels and 15,696 in multi-use PAs (Table 3.3).

Table 3.3. Treatment and control sampled pixels inside and outside Trifinio.

Pixel Status	Inside Trifinio Countries			
	Guatemala	Honduras	El Salvador	Total
Not PA	31,095	83,865	18,745	133,705
PA	6,219	16,773	3,748	26,740
Total	37,314	100,638	22,493	160,445
Pixel Status	**Outside Trifinio Countries**			
	Guatemala	Honduras	El Salvador	Total
Not PA	69,305	93,335	8,855	171,495
PA	13,861	18,667	1,771	34,299
Total	83,166	112,002	10,626	205,794

Before matching, the average speed of change in NDVI for unprotected pixels is slightly higher inside Trifinio compared to unprotected pixels in the 20-km buffer (0.27% vs 0.21%). The average increase in greenness is higher for protected pixels inside Trifinio with 0.34% compared to 0.23% outside. For the entire sample, all pixels inside Trifinio show on average higher increases in greenness (0.28%) relative to all pixels outside the region (0.21%). There are major differences in mean values of covariates across treated and control pixels inside and outside Trifinio. While protected pixels inside and outside Trifinio are on average about the same elevation around 1,600 m, the average elevation for unprotected pixels inside the region is 1,041 m compared to 885 m outside. Protected pixels inside Trifinio are on flatter slopes, closer to PA borders and roads but further from municipality and country capitals compared to outside the region. Treated pixels inside Trifinio are closer to PA borders than treated units outside, but further from capitals; the average values for slope (29%) and distance to roads (1.8 km) is about the same for pixels in both locations (Table 3.4).

Table 3.4. Average speed change in greenness (aNDVI) and summary statistics for PAs.

	Inside Trifinio			Outside Trifinio		
	Not PA	PA	All Pixels	Not PA	PA	All Pixels
aNDVI (1986-2016)	0.274	0.341	0.285	0.213	0.23	0.216
	(0.388)	(0.389)	(0.389)	(0.471)	(0.35)	(0.453)
Elevation	1041	1663	1145	884.6	1614	1006
	(359.4)	(469.2)	(445.1)	(373.30)	(656)	(511.56)
Slope	29.65	38.62	31.15	28.87	46.6	31.83
	(18.79)	(20.8)	(19.43)	(19.24)	(23.71)	(21.12)
Dist PA	8.4	2.81	7.47	28.48	26.5	28.16
	(5.88	(1.56)	(5.79)	(15.76)	(18.30)	(16.22)
Dist Road	1.86	2.70	20.06	1.8	3.67	2.11
	(1925)	(2.469)	(2.05)	(1.83)	(2.70)	(2.12)
Dist Mcap	8.69	8.18	8.6	6.7	7.53	6.84
	(8.18)	(3.79)	(7.63)	(10.15)	(3.24)	(9.36)
Dist Ccap	167.9	156.1	165.92	144.4	149	145.3
	(58.59	(54.97)	(58.16)	(53.10)	(39.07)	(51.06)

Standard deviation in ().

Elevation, slope, distances to the nearest PA border, roads, municipality capital and national capital were the covariates used for matching; the covariates listed in Table 3.5 did not pass Cochran's rule of thumb after matching because the maximum standardized difference in means is outside the 10% to 25% range.

Table 3.5. Covariate balance test after matching.

Inside Trifinio	Level	Failed Cochran's rule
Restriction	Strict	Dist PA, Dist Road
	Multi use	Dist PA
Country	Guatemala	Dist PA
	Honduras	Dist PA, Dist Road
	El Salvador	Elevation, Slope, Dist PA, Dist Mcap, Dist Ccap
Regional	All countries	Elevation
Outside Trifinio		
Restriction	Strict	Elevation, Slope, Dist PA
	Multi use	None
Country	Guatemala	None
	Honduras	Slope, Dist PA
	El Salvador	Elevation
Regional	All countries	Elevation, Dist PA, Dist Road, Dist Ccap

After matching by the level of restriction we find differences in how strict versus multi-use PAs affect aNDVI outcomes inside and outside Trifinio (Table 3.6). Inside Trifinio, strict PAs have significant and positive impact of 0.065% which means greenness increased for the 30-year period relative to areas outside protection. Multi-use PAs did not have a significant impact on aNDVI over the 30-year period compared to control pixels, which suggests that the change in greenness between the treatment groups is not different from zero.

Table 3.6. Estimated impact of PAs on LCLUC outcomes inside and outside Trifinio.

	Level	Effect	1986-2016	
			Inside Trifinio	Outside Trifinio
Restriction	Strict	ATT	0.065***	-0.014
			(0.006)	(0.014)
	Multi use	ATT	-0.007	-0.025***
			(0.006)	(0.013)
Country	Guatemala	ATT	0.014	-0.041***
			(0.027)	(0.009)
	Honduras	ATT	0.05***	-0.195
			(0.006)	(0.140)
	El Salvador	ATT	0.281***	-0.094***
			(0 .012)	(0.019)
Regional	All countries	ATT	0.032***	-0.0004
			(0.005)	(0.010)

*AI Robust Standard Error in () and statistically significant as *p<0.1, **p<0.05, ***p<0.01.*

The results for outside Trifinio are very different than results inside Trifinio. Strict PAs did not have a statistically significant effect over the 30-year period compared to unprotected pixels. Multi-use PAs had a significant and negative impact for the 30-year period of -0.126%—this suggests that multi-use PAs declined in greenness more rapidly than areas that were not under protection.

PA impacts by country vary across countries but follow similar trends to the overall differences between PAs inside and outside Trifinio reported above. For inside Trifinio, PAs in Guatemala have no significant statistical effect, thus NDVI changed at similar rates inside and outside these PAs. Outside Trifinio, the one PA in Guatemala had a small but negative impact on greenness with a reduction speed of -0.041% for the 30-year period. PAs in

Honduras have a positive and significant impact on greenness inside Trifinio with an increase rate of 0.05% for the 30-year period but no significant effect for PAs outside Trifinio. In El Salvador, PAs in this country have a positive and statistically significant impact inside Trifinio with an increase in greenness at 0.281% but the effect is negative and significant outside Trifinio and greenness decreased at -0.094%.

Considering all PAs in Trifinio Region, there is a significant and positive effect on LCLUC with increase in greenness for the 30-year period with a coefficient size of 0.032% compared to unprotected pixels in the region. There is no statistical effect from the 11 PAs in the 20-km buffer around Trifinio for the 30-year period on greenness which indicate aNDVI for pixels in the treatment groups is not different from zero (Table 3.6).

The matching regression results provide good information that help explain the ATT found in the PSM (Table 3.7). The fact that strict PAs have a positive impact on LCLUC compared to untreated pixels across Trifinio for the 30-year period may be due primarily to their location in relation to steeper slopes (47% compared to 28% for controls) and distance to roads (on average strict PAs in Trifinio are located at 4 km from roads and controls are on average at 1.8 km). This variable shows a positive and significant effect for the strict PAs sample in Trifinio which means as distance to roads increases NDVI. The negative effect from multi-use PAs outside Trifinio may be due to elevation and distance to PAs border based on the positive and significant effect of these covariates in the matching regression—as elevation and distance to PAs decreases the negative impact on aNDVI increases; multi-use pixels are on average located at much higher elevation (1000 m) than the controls pixels (885 m) and much closer to the PA border (18 m compared to 28 m for controls). The distance effects from municipality and national capitals seem to contribute to a positive effect from strict PAs in Trifinio which shows a small but positive and significant effect in the regression—this implies that pixels located close to markets show less impact. Blackman, Ávalos-Sartorio, and Chow (2012) found a similar relationship between proximity to markets, decreased vegetation in agroforestry systems, and natural forests cover.

The fact that all PAs within Guatemala inside Trifinio are multi-use may be the reason we find no significant effect on aNDVI outcomes for this country—the explanatory causes (e.g., distance to roads and municipality capitals) described above support this finding. Only one PA outside Trifinio in Guatemala was analyzed with multi-use management which for many years until 2016 was under co-management by the Municipality—it is now private lands and therefore there is little capacity to restrict resource use. Distance to roads and elevation negatively affect the performance of this PA in maintaining or increasing vegetation.

All PAs in Honduras and in El Salvador show significant and positive impacts in Trifinio but the results were insignificant for Honduras. The results were negative and significant in El Salvador outside Trifinio. All but one PA is strict and there are systematic differences in the covariates that are likely to contribute to this finding. On average PA pixels in El Salvador in Trifinio are at much higher elevation (1737 m) than outside Trifinio (1000 m) and much farther from roads—this indicates that pixels outside PAs are exposed to land uses with low NDVI values, mainly for agriculture activities like horticulture and coffee. Overall, PAs in Trifinio show a positive and significant impact for the 30-year period but PAs outside Trifinio have no significant impact—results in the matching regression show a positive and significant effect for treated pixels inside Trifinio.

Table 3.7. Matching regression estimations.

Inside Trifinio	Strict	Multi-use	Guatemala	Honduras	El Salvador	All Countries
Elevation	-0.0001***	0.00005***	0.0003***	-0.0001***	-0.00003	-0.0001***
	0.00001	0.00002	0.00006	0.00002	0.00003	0.00001
Slope	0.0010***	0.0007***	0.0005	0.001***	-0.002***	0.001***
	0.0002	0.0002	0.0005	0.0002	0.0006	0.0002
Dist PA	0.0015	0.0094***	-0.0268***	0.00001	-0.042***	0.005***
	0.0022	0.0023	0.009	0.002	0.008	0.002
Dist Road	0.00001***	-0.000001	-0.00004***	-0.00001***	0.0001***	0.00001***
	0.000002	0.000003	0.00001	0.000002	0.00001	0.000002
Dist Mcap	0.0042***	0.0004	-0.0081***	0.002***	0.022***	0.003***
	0.0007	0.0009	0.004	0.001	0.004	0.001
Dist Ccap	0.0013***	0.0017***	0.0048***	0.00001	-0.034***	0.002***
	0.0001	0.0001	0.001	0.0003	0.002	0.0001
Outside Trifinio	**Strict**	**Multi-use**	**Guatemala**	**Honduras**	**El Salvador**	**All countries**
Elevation	0.00001	0.00002**	0.0001	-0.00004	-0.00004	0.00002**
	0.00001	0.00001	0.00002	0.00004	0.0001	0.00001
Slope	-0.0001	-0.0005**	-0.0006***	0.0011***	0.0008	-0.0003*
	0.0002	0.0002	0.0003	0.0003	0.0008	0.0002
Dist PA	0.0019***	0.0011***	0.0011	0.00002	-0.0105**	0.002***
	0.0003	0.0003	0.0006	0.0008	0.0049	0.0002
Dist Road	0.0096***	0.0012	-0.0038***	0.0141***	-0.0185*	0.007***
	0.0021	0.0037	0.0054	0.0039	0.0097	0.002
Dist Mcap	-0.0005	0.0008	0.0016***	-0.0091***	-0.0069*	-0.00003
	0.0006	0.0006	0.0008	0.0012	0.0037	0.001
Dist Ccap	0.0015***	0.0020***	0.0019	-0.0001	-0.0162***	0.002***
	0.0001	0.0001	0.0003	0.0007	0.0034	0.0001

Standard errors in (). * $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Deforestation implies the long-term or permanent loss of forest cover and implies transformation into another land use or the maintenance of the clearings through continued disturbance (FAO, 2001). In areas like inside and outside Trifinio—where shifting agriculture, forest, forest fallow and agricultural lands appear in a dynamic pattern—deforestation and the return of forest occur frequently in small patches. Tucker, Munroe, Nagendra, and Southworth (2005) studied forest conservation and change in Honduras and Guatemala. Their study suggests there is ongoing forest fragmentation near transportation networks with strong linkages to coffee export markets in Guatemala and strong net deforestation, whereas Honduras is experiencing net forest regrowth. Another study by Nagendra, Southworth, and Tucker (2003) found that between 1991 and 1996 increased deforestation took place in areas distant from roads, and at higher elevations promoted by government policies for coffee. This study suggests that increased regrowth in accessible regions of the landscapes and regrowth mostly to the agricultural fallow cycle at the highest elevations but close to roads and abandonment plays a major role in landscape dynamics. While these studies do not use matching the results show similar findings as in our study. These are similar patterns to what we found inside and outside Trifinio. Land abandonment contributes to increases in greenness compared to other land uses that are short term but persistent like slash-and-burn subsistence farming and the use of local fires. Abandonment may be the consequence of changes in agricultural production or as an adaptation measure to changes in prices which are more likely to play a greater role as drivers of change across the landscape (Munroe, van Berkel, Verburg, & Olson, 2013). In our study sites even during periods of low commodity prices it is unlikely that abandonment contributes to increased aNDVI.

The countries that create the Trifinio Region cooperate in conservation actions through the Trifinio Plan but also with support from international donors that support this tri-national agreement. The Plan has set financial and technical cooperation goals for PAs in Trifinio in the form of training, development of management plans, equipment for fire control, communication systems, land surveys, and other actions. More importantly the Plan brings together PA managers and staff that regularly meet to coordinate activities aimed at increasing conservation effectiveness beyond national borders, connectivity between PAs, and cross-border management cooperation. We find evidence that these measures have brought positive outcomes for PAs within Trifinio compared to the 20-km buffer around it. Findings from this study are important to advance the theory and methods that explore national and transboundary PAs effectiveness in achieving conservation outcomes at multiple scales and for understanding their relationships to explain drivers of land use change and conservation policy effectiveness. Caveats to this study include that there are drivers of change that vary over time but cannot be controlled for in this study and that greenness in vegetation is susceptible to changes from multiple sources and so the outcome measure may be picking up signals that are not related to LCLUC.

Conclusion

We analyzed the impact of PAs on aNDVI outcomes in a transboundary conservation area to assess changes in vegetation patterns over a 30-year period since Trifinio was established as a transboundary region. The integration of remote sensing data with spatial econometrics to explore the causal effects of PAs according to management restrictions, by countries and across a tri-national political using a quasi-experimental approach to assess impact in the form of average treatment effect of PAs across space and time based on matching techniques.

By evaluating PA impacts across national borders and inside and outside Trifinio we find that overall, PAs inside Trifinio have had a larger impact on greenness than PAs just outside the transboundary area. There is, however, variation across PA types and countries, with strict PAs having an effect on greenness inside Trifinio but no effect from multi-use PAs. Outside Trifinio strict PAs have no effect on greenness and multi-use PAs have a negative impact. Across countries, Guatemala PAs did not have an effect whereas Honduras and El Salvador PAs did have positive effects on greenness inside Trifinio. For outside Trifinio PAs in Honduras show no significant effect whereas PAs in Guatemala and El Salvador show negative and significant effect. These differences suggest there are underlying processes operating within and across countries that need further studying to understand how the transboundary designation of the Trifinio Region is affecting LCLUC.

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Conclusions

The three main questions this dissertation answered were (i) what is the relationship between elements of governance of PAs and how this relates to PA challenges; (ii) what is the impact of PA governance on land cover outcomes; and (iii) what are the contributions from transboundary conservation to mitigate the impact from LCLUC. We integrated remotely sensed and qualitative data with spatial econometrics to explore the causal effects of PAs within a country, across national political limits, and inside and outside a transboundary region.

The analysis conducted in this dissertation shows that the relationship between elements of governance—decentralization, management capacity and management restrictions—are complex and this complexity is not easily captured in traditional assessments of PAs that only look at one aspect of governance (e.g. restriction in management). Focusing on management restriction alone when assessing impacts of PAs on LCLUC outcomes, as is traditionally done, leaves out important governance elements that are not perfectly correlated with one another. Exploring this question calls for deeper analysis and the use of mixed methods and more empirical studies to fully articulate all the potential pathways between governance and PA outcomes. The results presented here can serve as a guiding theoretical framework for future studies that explore the causal effect of interactions between decentralization in decision-making, capacity, and restriction on conservation outcomes.

We find some support for decentralization leading to better LCLUC outcomes decision-making, potentially because centralized management masks the potential benefits from community participation and stakeholder engagement in conservation approaches. PA capacity appears to have the largest influence on LCLUC outcomes and building PA capacity is key in the expansion of PA networks. We suggest increased focus and empirical studies measuring capacity and decentralization of PAs, and their interactions, in order to better understand these relationships across forested countries.

Based on our findings we can attest the importance of contextual factors and their effects on changes in PA management capacity and decentralization. The finding in from this dissertation show that overall, PAs inside Trifinio have had a larger impact on greenness than PAs just outside the transboundary area. But there is a lot of variation that takes place at country level. Exploiting the in-country factors that affect outcomes between countries is a subject for future studies. The findings in this study contribute to the ongoing debate of the benefits of crossing the line for conservation, and in fantastic places around the world, like the Trifinio Region. We provided evidence on the central linkages between decentralization theory and governance process that matter for PA design and how these factors play a major role in achieving desired conservation outcomes. More emphasis on studying the interactions of these governance elements is critical for the future of conservation through the establishment PAs.

Appendix A

Formulas to calculate annual change and annual rate of change in NDVI

Puyravaud (2003, pp. 594-595) provides formulas to calculate annual rate of change and annual change of deforestation (formulas 7 and 8). A_i refers to unit area of forest cover and t_i is time; both can be expressed in units of measurement or in percentage per time unit.

$$r = \frac{1}{t_2 - t_1} ln \frac{A_2}{A_1} \tag{7}$$

$$R = \frac{A_1 - A_2}{t_2 - t_1} \tag{8}$$

Formula 7 was adapted to calculate the annual rate of change in NDVI as

$$rNDVI = \frac{1}{year_2 - year_1} ln \frac{NDVI_2}{NDVI_1} \tag{9}$$

Formula 8 was adapted to calculate annual change in NDVI or the average speed at which NDVI changes per pixel per year where positive values indicate increase and negative values indicate reduction in vegetation greenness.

$$aNDVI = \frac{NDVI_2 - NDVI_1}{Year_2 - Year_1} \tag{10}$$

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Appendix B

Additional data and econometric results

NDVI and annual rate of change in NDVI (rNDVI) in percentage before matching.

Measure	Period	Mean	Std.Dev.	Min	Max
NDVI	1986	0.542	0.151	0.200	0.887
	1991	0.565	0.165	0.200	0.895
	1996	0.554	0.161	0.200	0.896
	2001	0.566	0.165	0.200	0.895
	2003	0.583	0.181	0.107	0.927
	2011	0.605	0.147	0.200	0.905
	2016	0.628	0.168	0.0718	0.934
rNDVI	1986-2016	0.494	0.740	-7.292	4.671
	1986-1991	0.688	3.655	-21.85	22.69
	1991-1996	-0.383	3.118	-24.32	23.16
	1996-2001	0.415	3.079	-23.32	25.27
	2001-2003	1.088	8.741	-75.06	58.67
	2003-2011	0.746	2.547	-15.06	20.29
	2011-2016	0.614	3.538	-42.45	25.05

Landsat images used per year to create NDVI dataset.

Landsat epoch per year	Number of images
1986	3
1991	2
1996	1
2001	3
2003	4
2011	2
2016	1

Sources for GIS and Excel databases.

Entity	**Source Notes**
Country Border	Central America Vector Data
Country Capital	Google Capital Locations
Muni Capital	Central America Vector Data
Ports	Provided by author
Roads	Trifinio Road Network (Comisión Plan Trifinio)
PA	GADM/Local Data Major discrepancies
Town 1K/5K	Geonames
Topography	SRTM
Proportion Protected	CM-Identified Measured in Raster, GADM N2 Data

Note: Samples were determined to be on or off roads by taking a distance measure from routes. If the sample point distance from the road was less than 31m, it was deemed to be on the road, and >31 it was off the road.

Appendix C

Cluster analysis method

Cluster analysis is a set of methods primarily used in exploratory data analysis to identify patterns, groups, or clusters in data—groupings that make sense based on similarities, dissimilarities, distances or proximity of observations or objects. These methods are useful in assessing whether or not observations that resemble each other can be summarized in relatively small number of clusters which are different in some way from other clusters (Everitt et al., 2011; Rencher & Christensen, 2013). The analysis may be conduct for clustering groups in the data on diagnostic categories, detecting similarities, spatial distribution, hierarchical relationships, identifying sets of similar geographically (Hamilton, 2012).

There are two broad approaches in clustering analysis methods for the selection of an optimal clustering scheme. One set of methods (non-hierarchical) rely on partitioning the data into a specified number of groups. These methods include k-means or k-median clustering which are not based on distance measures (e.g., Euclidean distance), but use the within-cluster variation of the data to form homogenous clusters. A second approach (hierarchical clustering techniques) is based on compactness where members of each cluster should be as close to each other as possible—the variance is minimized—and separation where the clusters themselves are widely spaced. The most commonly used methods in hierarchical clustering include Single-linkage (nearest neighbor) which measures distance between the closest observations but tends to produce unbalanced and straggly clusters; Complete-linkage (furthest neighbor) which measures distance between the most remote observations and tends to find compact clusters with equal diameters; Average-linkage uses average distances between all pairs of the two clusters' members, where members of a pair are in different groups and tends to join clusters with small variances with relatively robust solutions; and Ward's-linkage in which blending of two clusters is based on the size of sum-of-squares error criterion. Ward's method works well with groups that are multivariate normal but not so well with groups of different sizes or that have unequal numbers of observations. This method tends to find same-size, spherical clusters but is sensitive to outliers (Everitt et al., 2011; Rabe-Hesketh & Everitt, 2004). Finally, Everitt et al. (2011) suggest that Ward's and

Average-linkage are appropriate methods to use with continuous data—treating ordered data as continuous by standardizing based on range—as well as using Gower's similarity measure for mixed data. Also, hierarchical methods are suitable for binary data and for categorical data to be converted to binary format. The use of dissimilarity matrix is advice as an initial measure of concurrency in homogeneity or differentiation in groups and observations. The results of the dissimilarity matrix can then be used in a hierarchical clustering method.

Solutions from cluster analysis are intended for generating rather than testing hypotheses and are visually displayed as a tree diagram known as a dendrogram which aids in the selection of clusters that are optimal for the research (Hamilton, 2012). After deciding which cluster methods to use for the analysis, the next problem is selecting the number of cluster generated from observations in the dataset. One procedures to solve this problem is using stopping rules like Caliński and Harabasz pseudo-F index and the Duda–Hart Je(2)/Je(1) index in which values— larger or small depending on the rule—indicate more distinct clustering. Large values of the Caliński –Harabasz pseudo-F index indicate distinct clustering. A large Je(2)/Je(1) index value and a small pseudo-T-squared value indicate distinct clustering (StataCorp, 2015a). While the former can be used in hierarchical and non-hierarchical clustering the later work only with a hierarchical cluster analysis (StataCorp, 2015). The alternative is to use a dendrogram (or tree diagram) which is a graphic mathematical representation of the complete clustering procedure with solution outcome showing the particular partitions or clusters. Each observation conforms a unique cluster at the bottom of the dendrogram. Each observation has a vertical line connecting other observations with a horizontal line. Horizontal lines define clusters and the vertical distances show (dis)similarity values and the distance of the lines indicate more or less distinct separation between the groups—shorter vertical lines indicate similarity. The groupings continue and end at the top of the dendrogram where all observations conform a single cluster. The number of clusters to select from a dendrogram is based on the differences in height (y-axis) where a horizontal partition across all observations determine that clusters below that height are (dis)similar from each other at the value of the difference in height from other horizontal partitions (StataCorp, 2015b). Thus, the graphic display of the dendrogram can informally suggest the number of clusters to select—the large change in height indicates the best horizontal cut. (Everitt et al., 2011).

We conducted several tests to classify PAs by their level of decentralization and management capacity using several hierarchical cluster methods (Ward's, Average, Single and Complete linkages) and variable standardization combinations. We dropped all variables with more than two missing values in the any observation. We then ran a matrix dissimilarity with Gower procedure using the selected variables and range standardization. In general, most of the solutions from the cluster methods were very similar but not exactly the same which can be expected. Given this result and as suggested by the literature, we decided to proceed the analysis only using wardslinkage with Gower on the matrix dissimilarity because it preforms better for this type of analysis than the alternative method and it also allows the for use of missing values in the observations.

Likert scale analysis method

A Likert scale is constructed based on the assumptions that (i) it is possible to measure the underlying phenomenon by aggregating individual scores of feelings, attitudes, or perceptions related to a series of statements or items (Harpe, 2015) largely guided by the aim of the study, and (ii) that these combination reveal the specific dimension of the attitude towards the issue because the statements are necessarily inter-linked with each other (Joshi et al., 2015). For the analysis of Likert scale is important to consider that separating the items conceptually "breaks" the theoretical measurement properties of the aggregated scale (Harpe, 2015).

Depending on its use a Likert may be considered as ordinal, interval, or as continuous measurement scale. Analysis of a Likert scale from an "ordinal" perspective should only use descriptive statistics like mode, median, frequencies, or percentages of response in each category to show variability—analysis based on mean and standard deviation do not fit these type of data (Boone & Boone, 2012; Jamieson, 2004). An analysis from an interval view imply that combining all items in the scale can generate a 'composite' score per individual rather than conducting an analysis of single item responses by all individuals, thus, generating a realistic distance between scores across individuals as 'interval estimates'" (Joshi et al., 2015); some authors consider Likert scales as a continuous variable (Clason & Dormody, 1994; Joshi et al., 2015).

Joshi et al. (2015) suggest that for constructing a Likert scale to later create a single composite index is important to select items that are closely interrelated but provide some independent information as well; arrange items in a logical sequence in a way that there is some element of 'coherence/expectedness' between responses; and that each item measures a distinct element of the issue. It is important to have items that are reversed in meaning from the overall direction of the scale (i.e., reversal items) and reverse the response value for each of these items before summing the total (Trochim & Donnelly, 2001). Finally, Carifio and Perla (2007) suggest a minimum number between six to eight items to form a scale to increase reliability, validity and generalizability.

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Appendix D

Entrevista sobre la Gobernanza y Eficacia a Personal de APs en Trifinio
[No lea al informante lo que está entre corchetes]
[Introducción y declaración de confidencialidad]

Buenos días/Buenas tardes. Mi nombre es _____. Esta entrevista es parte de un estudio acerca del proceso de toma de decisiones y el manejo de las áreas protegidas (APs) localizadas en la región conocida como Trifinio. Soy investigador de la Universidad de Idaho en los EE.UU. y estoy colaborando con el CATIE y la Comisión Trifinio.

Somos conscientes de que las APs son administradas por una autoridad central, pero dependiendo de la categoría del AP, la legislación nacional también permite a otros actores participar en los procesos de toma de decisiones y el manejo. Algunos de los temas que me gustaría discutir se refieren a los cambios en los niveles de la distribución de autoridad y poder para la gestión y la toma de decisiones relacionadas con el AP ____ [*diga el nombre del AP*]. Mi interés con esta entrevista es entender la forma en que se da la distribución de: (i) la autoridad para la toma de decisiones y (ii) las responsabilidades para el manejo, en el marco de la estructura de gobernanza del AP. Es decir, desde el nivel político-administrativo de las APs en ____ [*diga el país, El Salvador, Guatemala, Honduras*] y entre el AP ____ [*nombre el AP*] y actores pertinentes. Otro de mis intereses es hablar sobre (iii) la capacidad administrativa del AP. Por último, me interesa también en (iv) cómo estos factores (redistribución de autoridad, responsabilidades en el manejo y capacidad administrativa) pueden haber cambiado con el tiempo. Para recopilar esta información, voy a hacer preguntas relacionadas con factores como, la administración, la financiación, la capacidad, los retos y amenazas, fuerzas locales y regionales y oportunidades.

Quisiera aclarar, primero, por favor sepa que no soy representante del gobierno, la Comisión Trifinio o CATIE. Segundo, su participación en esta entrevista es confidencial y voluntaria, usted tiene el derecho de terminarla en cualquier momento. Si usted prefiere no responder a una pregunta, por favor hágamelo saber y podemos continuar la entrevista con las preguntas siguientes. La entrevista durará de 60 a 90 minutos. Recuerde que toda la información recopilada será tratada de forma confidencial y es sólo para fines de investigación. Esta entrevista ha sido aprobada por la Junta de Revisión Institucional de la Universidad de Idaho.

[El informante puede estar interesado en saber cómo él/ella fue seleccionado para la entrevista o en información general. Permita un momento para preguntas generales.]

¿Podría comenzar la entrevista? Sí No [marque la respuesta].
¿Estaría bien grabar nuestra conversación? Sí No [marque la respuesta].

¡Gracias! Hora de inicio: ______

A. Generalidades del AP

1. Nombre de la persona informante ________________________________
2. Puesto ____
3. Años de laborar en el AP ________
4. Nombre del AP ____
   4.1. País __________________________
5. Año de declaratoria __________
6. Área en hectáreas ______________
7. Categoría de manejo según la legislación nacional ______________________
   7.1. Equivalente en el sistema de la IUCN _______________
8. Municipio(s) en el que se ubica el AP _____________________________

B. Misión, metas u objetivos del AP

9. ¿Cuál es el propósito primario de esta AP?

   9.1. ¿Cuáles son las principales actividades que realiza esta AP? Piense en lo que sucede dentro y fuera del AP.

10. ¿Qué características hacen de esta AP de especial importancia (por ejemplo, aspectos biológicos, geológicos, históricos o arqueológicos)? Por favor de algunos ejemplos.

C. Estructura institucional, administración y nivel de descentralización del AP

11. ¿Qué agencias de gobierno son responsables de esta AP?

    [Preguntas 11.1 y 11.2 SÓLO si hay varias agencias co-responsables]

    11.1. ¿Cómo coordinan esas agencias sus esfuerzos de gestión?
    11.2. ¿Cómo se apoyan mutuamente en sus trabajos para el AP esas agencias?

12. Explique cómo las autoridades centrales se involucran en la definición de regulaciones y acciones de manejo para esta AP.

13. ¿Cómo es nombrado el director o la persona responsable de esta AP?

    13.1. Por favor describa cómo esta persona (usted) toma decisiones del manejo del AP

14. ¿Esta AP tiene un plan de manejo escrito? [Si responde No pase a la pregunta 15]

    14.1. ¿Quién desarrolla y aprueba las regulaciones del plan de manejo para la AP?
    14.2. ¿Hace cuánto tiempo se hizo el actual plan de manejo?

14.3. ¿Con qué frecuencia se supone que el plan de manejo debe actualizarse?
14.4. ¿Qué tan importante es el plan de manejo para orientar la toma de decisiones en el AP?

15. ¿Cómo ha cambiado el manejo de esta AP durante los últimos 5 a 10 años?

15.1. ¿Cómo ha cambiado la toma de decisiones?

D. Capacidad institucional y administrativa del AP

16. ¿Cuáles son las principales fuentes de financiamiento de esta AP, en porcentajes?

17. ¿El presupuesto anual fluctúa de año en año?

17.1. [En cualquier caso] ¿Por qué?
17.2. [En caso que Si], ¿Cómo impacta esta fluctuación al AP?

18. ¿Cómo se asigna el presupuesto a las diferentes actividades del AP, en qué porcentajes?

19. Hablemos sobre el personal del AP en general. ¿Cuál es el total de personal

a. asalariado ___
b. voluntarios ___
c. técnicos (e.g., biólogos, maneja recursos, educadores ambientales, coordinadores de proyectos, etc.) ___
d. patrullaje y control ___
e. administración y oficina ___

19.1. ¿Es el personal actual suficiente para la administración del AP?
19.2. ¿Qué cambios ha visto en el AP como resultado de los trabajos del personal?

20. ¿Qué datos están disponibles relacionados con el AP? Por ejemplo, permisos, impuestos, tarifas por servicios, número de visitantes, etc.

E. Vínculos e involucramiento con actores relevantes externos y comunidades

21. ¿Con qué frecuencia mantienen reuniones con actores relevantes externos para discutir decisiones y asuntos de manejo que son importantes para esta AP?

21.1. Si responde No, ¿Por qué? [Si responde NO pasa a la pregunta 22]
21.2. ¿Quiénes son esos actores? ¿Son sobre todo los actores y las comunidades locales u organismos internacionales (por ejemplo, ONGS, grupos no formales, UNESCO, Ramsar, CDB)?

21.3. ¿Cuándo inició esta práctica?
21.4. Explique las formas en que los actores relevantes externos se involucran con el AP en la definición de normas y acciones para el manejo de esta AP?
21.5. ¿Qué beneficios obtienen los actores relevantes al involucrarse o participar en la toma de decisiones y la gestión de esta AP? [Si es necesario preguntar sobre transferencias financieras, deducción de impuestos ganancias políticas, prestigio, etc.]

22. ¿Existen acuerdos de co-manejo o co-administración?

22.1. De ser así, ¿Con quién?

23. ¿De qué forma influencia la toma de decisiones y el manejo la ubicación de esta AP en la Región Trifinio?

24. Describa la relación entre esta AP y la Comisión Trifinio.

24.1. ¿La Comisión Trifinio se involucra en la formulación de regulaciones y medidas de manejo de esta AP?
24.2. [En caso que SI] ¿Cómo? [Continúe con la pregunta 24.4]
24.3. [En caso negativo] ¿Por qué no?
24.4. ¿Qué tan importante es la Comisión Trifinio para esta AP y por qué?
24.5. ¿De qué manera la cooperación entre los tres países o el Acuerdo del Plan Trifinio influye en su toma de decisiones y el manejo?

25. ¿Hábleme de la relación entre el AP y las comunidades cercanas?

25.1. ¿Cómo cree que se siente la gente local con respecto a ésta AP?
25.2. ¿Cómo ha cambiado la relación entre el AP y las comunidades locales en los últimos 5 a 10 años?

26. ¿Hay conflictos de tierras entre el AP y las comunidades locales (por ejemplo, acceso, derechos de uso y seguridad sobre los derechos sobre la tierra)?

26.1. [En caso que Si] ¿Cómo enfrenta el AP esos asuntos de tierras?
26.2. ¿Puede mencionar un ejemplo de esos conflictos?

27. ¿Hay otros grupos que ofrecen programas/proyectos comunales relacionados con conservación (por ejemplo: reforestación, educación ambiental, investigación, extensión, prácticas de manejo de bosque y otros medios de vida, etc.)?

27.1. De ser así ¿El AP colabora con alguno de esos programas?
27.2. ¿En cuáles programas/proyectos el AP colabora con las comunidades?
27.3. ¿Cómo se financian esos programas/proyectos?

28. ¿Puede nombrar las 3 comunidades más activas alrededor del AP (por ejemplo, con las mejores organizaciones y redes locales relacionadas con la misión de ésta AP)?

29. ¿Cómo aprovecha usted las fuentes de conocimiento local en los procesos de toma de decisiones y manejo de esta AP?

F. Percepción de amenazas y desafíos

30. Por favor, ordene con números las siguientes actividades según la influencia que ejercen en cambios en el AP. El número 1 indica la mayor importancia, el 2 un poco menos y así sucesivamente. NA indica "No Aplica".
    1. Explotación forestal
    2. Conversión de bosque a cafetales
    3. Conversión de bosque a pastizales
    4. Conversión de bosque a sistemas agroforestales
    5. Conversión de bosque a otros tipos de agricultura
    6. Cacería
    7. Extracción de vida silvestre (por ejemplo, pájaros, orquídeas, plantas)
    8. Carreteras
    9. Urbanización (población que emigra o población que inmigra)
    10. Incendios
    11. Minería
    12. Otros _______________

31. Por favor, ordene las siguientes actividades según la influencia que ejercen en cambios en los alrededores del límite del AP. El número 1 indica la mayor importancia, el 2 un poco menos y así sucesivamente. NA indica "No Aplica".
    1. Explotación forestal
    2. Conversión de bosque a cafetales
    3. Conversión de bosque a pastizales
    4. Conversión de bosque a sistemas agroforestales
    5. Conversión de bosque a otros tipos de agricultura
    6. Cacería
    7. Extracción de vida silvestre (por ejemplo, pájaros, orquídeas, plantas)
    8. Carreteras
    9. Urbanización (población que emigra o población que inmigra)
    10. Incendios

11. Minería
12. Otros _____________

32. ¿Cuáles son los principales desafíos y amenazas del AP?
1 = Cacería y extracción de vida silvestre, 0 = Si no es el caso
1 = Deforestación, 0 = Si no es el caso
1 = Fuegos, 0 = Si no es el caso
1 = Aspectos administrativos, falta de fondos y personal, 0 = Si no es el caso
1 = Political, ambitious policy does not fit PA's reality, 0 = Si no es el caso

32.1. ¿Cómo los enfrentan?
32.2. ¿Puede mencionar un ejemplo de esta situación?
32.3. ¿Cómo han cambiado las amenazas y desafíos enfrentados por el AP en los últimos 5 a 10 años?

33. ¿Podría nombrar de 3 comunidades alrededor del AP con las que han tenido mayores dificultades por actividades ilegales relacionadas con la conservación de los recursos naturales tanto dentro como fuera del AP?

34. ¿Sabe usted si ésta AP siempre ha estado cubierta por bosque o si en el pasado la tierra se dedicó a otras actividades humanas?

[La siguiente tabla se le entregará al entrevistado para que la complete. Asegúrese que el entrevistado entiende el uso de la escala y el proceso de selección de las respuestas. Ofrezca ayuda adicional si fuera necesario.]

[Deje tiempo para preguntas o comentarios que el entrevistado pueda tener. Tenga un gesto de gratitud para el entrevistado por su participación]

Tiempo de finalización: ______

De las frases contenidas en la siguiente tabla, por favor seleccione el número que representa mejor su opinión sobre la toma de decisiones, administración y capacidades en esta AP.

Escala Likert sobre descentralización

	Totalmente en desacuerdo	En desacuerdo	Ni en acuerdo ni en desacuerdo	De acuerdo	Totalmente de acuerdo	No contesta o no sabe
35. Hay una dependencia muy fuerte de las autoridades centrales en la toma de decisiones para el AP.	1	2	3	4	5	0
36. El proceso de toma de decisiones en el AP está libre de influencia política.	1	2	3	4	5	0
37. Los procesos de toma de decisiones en el AP se hacen de manera transparente.	1	2	3	4	5	0
38. Los procesos de toma de decisiones en el AP se hacen en coordinación con las agencias del gobierno pertinentes.	1	2	3	4	5	0
39. Los límites del AP están	1	2	3	4	5	0

	Totalmente en desacuerdo	En desacuerdo	Ni en acuerdo ni en desacuerdo	De acuerdo	Totalmente de acuerdo	No contesta o no sabe
claramente demarcados.						
40. Los límites del AP son claramente conocidos por los actores relevantes y comunidades.	1	2	3	4	5	0
41. Las autoridades responsables de ésta AP con frecuencia comunican públicamente las propuestas sobre políticas forestales y de conservación, programas y proyectos para el AP.	1	2	3	4	5	0
42. Los actores relevantes tienen oportunidades de revisar y dar aportes para propuestas sobre políticas forestales y de conservación.	1	2	3	4	5	0

De las frases contenidas en la siguiente tabla, por favor seleccione el número que representa mejor su opinión sobre la toma de decisiones, administración y capacidades en esta AP.

Escala Likert sobre capacidad

	Totalmente en desacuerdo	En desacuerdo	Ni en acuerdo ni en desacuerdo	De acuerdo	Totalmente de acuerdo	No contesta o no sabe
43. Los procesos de toma de decisiones para el AP están abiertos a la participación de los actores relevantes.	1	2	3	4	5	0
44. Los actores relevantes y las comunidades están suficientemente involucrados en los procesos de toma de decisiones.	1	2	3	4	5	0
45. La realimentación que brinden los actores relevantes es usada en los proceso de toma de decisiones del AP.	1	2	3	4	5	0
46. Las denuncias de presuntas actividades forestales ilegales en el AP o sus	1	2	3	4	5	0

	Totalmente en desacuerdo	En desacuerdo	Ni en acuerdo ni en desacuerdo	De acuerdo	Totalmente de acuerdo	No contesta o no sabe
alrededores son investigadas.						
47. Las denuncias de presuntas actividades forestales ilegales en el AP o sus alrededores son sancionadas apropiadamente.	1	2	3	4	5	0
48. El AP tienen suficiente financiamiento para cubrir sus operaciones	1	2	3	4	5	0
49. El equipo y la infraestructura del AP es suficiente para su administración.	1	2	3	4	5	0
50. El personal es suficiente para la operación del AP.	1	2	3	4	5	0