

# DECENTRALIZED FORESTRY IN GUATEMALA: A TEST OF POLYCENTRIC GOVERNANCE THEORY

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## Abstract

What are the drivers of sub-national variation in forestry outcomes under a uniform national decentralization policy? The literature on decentralized governance of natural resources in developing countries is decidedly mixed in terms of theory and findings. Some scholars argue that decentralization reforms will lead to improved policy outcomes, other scholars view decentralization with great skepticism, and a third group believes that whether governance reforms will lead to positive or negative environmental outcomes is conditional on an array of ancillary factors. Unfortunately, many empirical investigations of decentralization's effects fail to evaluate these competing explanations under circumstances where there are tangible tradeoffs pushing actors toward disparate environmental outcomes. Our contribution to this policy-relevant debate involves innovations in both theory and empirics. First, this study builds upon and applies polycentric governance theory, arguing that the strength of connections between actors across levels of government shapes forest cover change under decentralization. Specifically, we hypothesize that municipalities exhibiting higher levels of polycentricity will be more effective in improving forest conditions. Second, we test this theory using a unique longitudinal dataset on forestry governance for 100 municipalities in Guatemala, combining socio-economic information, two waves of surveys with mayors, and remote-sensed data on forest change over twenty years. Preliminary results suggest that governance systems characterized by higher polycentricity are able to counteract the pressures towards deforestation when agriculture is important for a municipality, whereas those with lower polycentricity are not.

# 1 Introduction

Why are some municipalities in Guatemala able to improve forest conditions under the country's decentralization policy while other municipalities are not? Stemming deforestation in tropical countries throughout the developing world has been identified as a major policy priority by international organizations due to its links to poverty, underdevelopment, and climate change. Donors continue to incentivize developing countries to decentralize the management of forestry resources as a solution to deforestation, but there is still relatively little consensus on whether these reforms are effective, and if so, under what conditions. This study draws on work in polycentric governance theory to argue that the effectiveness of decentralization policies will be conditional on local-level governance structures and the extent of linkages among actors across levels of government. Specifically, we hypothesize that mayors working in governance systems that are characterized by higher levels of polycentricity – where municipal authorities are more strongly connected to local, regional, and national organizations – will be more likely to have success in improving forest conditions within their municipalities. We test this primary hypothesis derived from polycentric governance theory using a unique panel dataset on forest outcomes and institutional conditions for a representative sample of 100 municipalities in Guatemala, a country that has one of most extensive implementations of decentralization in its forestry sector and where municipalities face varying pressure to convert forested land for agriculture use.

We address our primary research question through the following steps: section 2 discusses existing findings on the effects of decentralization, section 3 details the decentralization reform within the Guatemalan forestry sector, section 4 presents polycentric

governance theory and lays out the primary hypothesis for this study, section 5 consists of our empirical strategy and analysis, and section 6 concludes.

## **2 Findings on the Effects of Decentralization**

The goal of this study is to better understand the drivers of local variation in forestry outcomes under a uniform national decentralization policy. Decentralization reforms are an attempt to stem deforestation through changes in the vertical distribution of power across levels of government and between the public, private, and non-governmental sectors. Whether or not these reforms are actually able to achieve their goals is largely an open question; the academic literature on decentralization varies widely in its theoretical bases, geographical coverage, and themes, and is characterized by significant theoretical and empirical disagreements.

Proponents of decentralization argue that local actors are better positioned to make decisions and implement policies because they have access to superior information relative to their national counterparts and because they are more directly accountable to local constituents (Hayek 1945, Oates 1977, Diamond & Tsalik 1999). This causal logic hinges on matching information and accountability structures to the policy problem at the appropriate level of authority. Thus, problems that have confined or local effects are best addressed by governance actors situated at the same local level who will be responsive and accountable to the individuals affected. The general conclusion among proponents is that devolving decision-making to regional and local actors will ease informational shortcomings, clarify accountability, and ultimately lead to more appropriate decisions.

Skeptics of decentralization, however, highlight that devolving political decision-making can reinforce and entrench existing local power dynamics to the detriment of the poor (Crook &

Manor 2000, Agrawal & Ribot 1999). This perspective focuses on the relative weakness of formal institutions generally, and local institutions especially, in many countries where decentralization reforms have been implemented. Most importantly, these scholars are concerned with the possibility that elites have captured or will be able to capture local institutions. Therefore, empowering local governing bodies will actually allow elites to further enrich themselves and/or target resources in a way that reinforces their standing within the community. Institutional weakness and corruption are likely to hinder decision-making at the local level, and thus skeptics expect decentralization reforms to have negative consequences.

Finally, a third group of scholars emphasize that implementing decentralization reforms does not automatically translate into outcomes, positive or negative. Instead, they argue that it is crucial to analyze the processes in the middle of a causal chain linking interventions with outcomes, and thus prefer conditional hypotheses about the effectiveness of decentralization. Scholars in this group have arrived at four core findings. First, positive outcomes from decentralization are unlikely without popular participation in local government decision-making (Singleton 1998, Blair 2000, Larson 2002, Andersson & van Laerhoven 2007, Agrawal & Ribot 1999, Agrawal & Ostrom 2001). Second, positive outcomes from decentralization rely on local governments being downwardly accountable to citizens (Crook & Manor 1998, Smoke 2003, Ribot 2002, Yilmaz & Serrano-Berthet 2008). Third, successful decentralized governance hinges on the technical capacity of the local unit to which governance responsibilities are devolved (e.g., Andersson 2004, World Bank 1988, Pacheco 2000, Flores & Ridder 2000, Contreras & Vargas 2001). And fourth, without a secure source of funding, local governments will be unable to provide consistent, quality public services (Fiszbein 1997, de Mello 2000, Kaimowitz et al. 2000, Pacheco 2000).

Moving beyond these theoretical claims and empirical findings from the broader literature, studies focusing specifically on decentralization in the forestry sector make two major points: 1) there is significant and meaningful subnational variation in outcomes within countries that have implemented national decentralization policies, and 2) there is little to no consensus in the literature about which factors explain this variation (Andersson & Ostrom 2008, 88; Nagendra & Ostrom 2012, 117). Scholars have alternatively pointed to effective monitoring and rule enforcement (Gibson et al. 2005), financial and political incentives for local politicians, involvement and pressure from local civil society groups (Andersson 2003, Gibson & Lehoucq 2003, Andersson et al. 2006, Kauneckis & Andersson 2009), and strong local institutions (Andersson & Gibson 2006) as relevant for understanding successful local management of natural resources, decision-making by local politicians with respect to forestry, unauthorized deforestation, and forest cover change broadly. In short, there are significant uncertainties about the conditions and factors that drive variation in forest outcomes under decentralized governance regimes. The present study is an attempt to move this research agenda in a productive direction by leveraging insights from polycentric governance theory, rigorously testing those insights with high-quality longitudinal data, and considering circumstances where the incentives to cut down forests for agricultural production are both material and clear.

### **3 Forestry Sector Decentralization in Guatemala**

A natural question emerges from the arguments about decentralization and its effectiveness in developing countries: what abilities do local actors – politicians, civil society organizations, and forestry officials – have to affect environmental change and deforestation? Like many other scholars (Andersson, 2002; Gibson & Lehoucq, 2003, and Andersson et al.,

2010 as just a few examples), we anchor our analysis of social-ecological systems in Guatemala around local mayors for the very reason that they are the key governance actors with both political authority and financial resources to affect forestry outcomes. These authorities and resources result directly from the forestry decentralization reforms implemented throughout Guatemala during the 1990s.<sup>1</sup>

Guatemalans suffered an extended period of civil war and military rule up until the late 1980s and early 1990s. In 1985, the ruling military regime convened a national Constituent Assembly that implemented a new constitution for the country. In that document, 8% of the national budget was allocated for transfer to the country's municipalities (this was raised to 10% through an amendment in 1994). Additionally, the new constitution provided for the direct election of mayors and municipal councilors. These changes significantly raised the profile of municipal politics (and municipal politicians) in the country.

Furthermore, in 1996 Guatemala passed its national Forestry Law that devolved substantial forest management and administration responsibilities to municipal governments from the central government. The law had two major provisions. First, municipalities became responsible for running the forest supervision system within their territory (in cooperation with the National Institute of Forestry) in order to prevent exploitation of forestry resources. Second, the national government implemented a system of financial incentives for municipalities undertaking reforestation projects and managing natural forests. In addition to these major changes, the law also endowed municipal governments with ancillary responsibilities and powers.

The municipal council, headed by the mayor, gained the mandate to provide technical advice to

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<sup>1</sup> Our description of forestry decentralization in Guatemala draws on information in Government of Guatemala (1996) as well as descriptions in Gibson & Lehoucq (2003) and Andersson et al. (2006). For additional details about the landscape of decentralization reforms in Guatemala see Ferroukhi & Echeverria (2003), Puente Alcaraz et al. (2004), and FLASCO (2002).

local forest users and to assist the central authority in enforcing all forestry laws. Additionally, they obtained the authority to collect taxes on certain forestry activities, charge user fees for some forestry services, and impose fines on individuals violating forestry laws and regulations. Finally, the law allowed municipal governments to own forested land, to manage that land according to their own rules (including the ability to rent it), and to cede responsibility for managing certain lands to rural communities through local agreements.

Together, the 1985 constitution and the 1996 Forestry Law drastically changed the balance of authority and responsibility between the national government and the municipalities over forestry: local mayors were given a clear directive to act in the forestry sector. The ways in which they responded to that directive and the success of those responses, however, varied. Some mayors took ownership for policy development and implementation in the forestry sector within their municipalities, thereby affecting deforestation and environmental change, sometimes with positive results and sometimes negative, while others did not. Mayors are the key governance actors situated between the national level decentralization reforms and local forests, but they are clearly not the only such actors. The argument we elaborate in the next section is that the primary social factor driving forest change under a decentralized governance regime is the strength of the relationships between the mayor and other relevant stakeholders across multiple levels of government who are involved in the forestry sector.

#### **4 Polycentric Governance Theory and Social-Ecological Systems**

The concept of a social-ecological system emphasizes the complex and interdependent relationships between humans, institutional rules, and natural resources (Ostrom 2009). In this study, social-ecological systems are anchored by the municipal council, the mayor and his

immediate advisors, and encompass governmental and non-governmental actors at local, regional, and national levels who influence forest cover change within a given municipality. Furthermore, we use the Institutional Analysis and Development (IAD) Framework to structure our investigation of institutional arrangements and forest cover change in Guatemala. Within this framework, institutions are defined as human-devised rule structures that incentivize and constrain individual behavior (North 1990), and the polycentricity of a governance system refers to the degree to which decision-making is influenced by multiple, autonomous authorities with overlapping jurisdictions (Ostrom et al. 1961, Ostrom 2005).

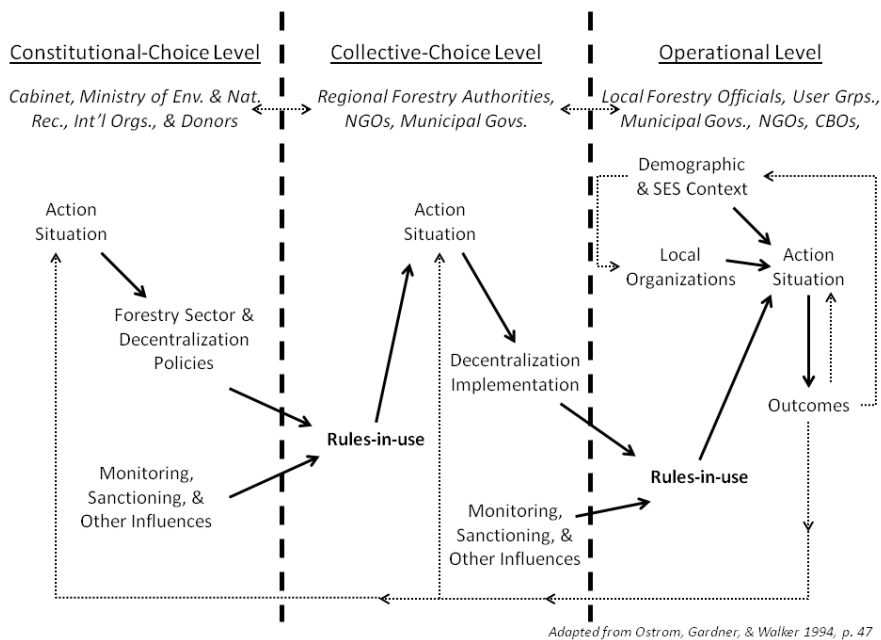
The IAD Framework provides a systematic approach for conceptualizing and analyzing the logical relationships among these authorities, their decision-making processes, and subsequent outcomes across governance levels. Figure 1 presents a diagram of the decision-making structure related to forestry in Guatemala based on this framework. Three governance levels characterize the sector: operational, where individuals and organizations take actions and affect outcomes; collective-choice, where rules defining and constraining operational-level behavior are created; and constitutional-choice, determining the rules for making rules. Each level has its own action situation consisting of the interactions between different individuals and organizations who can affect decisions—and which are influenced by various conditions, such as monitoring, prior outcomes, and socioeconomic factors. The action situation bounds the analysis by defining where interactions among actors occur and social choices are made.

As already discussed, for the purposes of understanding subnational variation in forest cover change under a uniform decentralization regime, we choose to focus our analysis in this study on the municipal council at the operational level. The mayor, his immediate advisors, local community organizations, and user groups are the key stakeholders whose decisions and actions



have the most direct effects on forests within the municipality. Moreover, the decentralization reform situates extensive authorities and responsibilities for forest management with these very actors, chiefly the mayor and his council. That said, what the IAD framework and polycentric governance theory make clear is that local actors do not make their operational decisions within a vacuum. Instead, the incentives they face are structured by a complex network of relationships from the local level, through the regional level, and up to the national government. As a result, decisions taken by the municipal council with respect to forestry cannot be adequately understood without reference this network of relationships. In short, the ideas of polycentric governance within the IAD framework enable us to highlight the importance of connections between municipal actors and multiple other organizations across levels of government in affecting forest cover change, a relationship which we discuss in greater detail in the next section (Ostrom 2005, Andersson 2006, McGinnis 1999, Lieberman 2011).

Figure 1: IAD Framework and Polycentric Governance Applied to Social-Ecological Systems for Forestry in Guatemala



## 4.1 Hypotheses

The theoretical contribution of this study is to situate the analysis of the drivers of forest cover change firmly in polycentric governance theory where organizations work in complex, interdependent systems and their interactions within and across governance levels are pivotal for local outcomes (Ostrom 2005). Through this approach, we highlight how the configuration of institutional arrangements shapes variation in forestry outcomes under a uniform national decentralization policy. Building on Andersson & Ostrom (2008) and Nagendra & Ostrom (2012), we hypothesize that the degree to which municipal actors are connected to local- and national-level organizations – how they are accountable, leverage resources, and gain external support – will affect forest cover change. Specifically, increases in the degree of polycentricity within forestry governance systems will be associated with positive forest cover change.

The rationale for this primary hypothesis is that the complex economic, social, and cultural drivers of forest cover change make it unlikely for the municipality to be successful on its own; municipal actors need the influence and contributions of external governance actors, both those below and above them in the government hierarchy, to counteract pressures for deforestation at the local level (Andersson 2004, Andersson & Ostrom 2008, Nagendra & Ostrom 2012). To illustrate, we would expect forest conditions to improve in a governance system where forestry officials, the mayor, and civic groups collaborate frequently, are monitored by the forestry authority, gain support from a regional NGO, and can access incentives for reforestation projects from the national government. In this type of governance system, mayors who are inclined to preserve forests are not alone or isolated in resisting local pressures for development and deforestation. Similarly, mayors who might be inclined to

appease local development interests, perhaps by allowing the conversion of forested land to agriculture, are also less able to take such actions unilaterally when they are strongly connected to multiple organizations across levels of government. In both cases, higher polycentricity will be associated with positive change in forest cover. In parallel fashion, the types of unilateral actions that extract from a collective good like forested land for the benefit of potentially narrow interests are more easily taken in isolation when the mayor and his council do not maintain strong connections to diverse organizations across levels of government. And, unilateral actions to prevent deforestation or spur reforestation activities will also be more difficult to undertake in isolation and without connections to local and national entities with a stake in the forestry sector. In both of these circumstances, lower polycentricity is more likely to lead to negative change in forest cover.<sup>2</sup>

Finally, we argue that a relevant test of polycentric governance theory must consider cases where there are competing pressures that make certain decisions more costly than others. With respect to decentralized forestry in Guatemala, this means explicitly characterizing the incentives motivating mayors to deforest land and examining the effects of the institutional structures in moderating those incentives. Where there are few or weak pressures for development, and thus little cost associated with leaving forests in their natural state, the level of polycentricity is largely immaterial to the overall outcome. Forests are likely to remain standing. But, it is exactly under circumstances of significant pressure to develop, and tangible costs of avoiding deforestation, that the effect of governance structure can be observably important.

Therefore, the most difficult test of our hypothesis about polycentricity involves examining the

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<sup>2</sup> The overarching logic motivating our primary hypothesis holds up if there is even modest heterogeneity in preferences among the relevant actors. This logic would be subject to greater criticism if there was perfect alignment in preferences among actors across levels of government, but we believe this circumstance is exceedingly rare and not a realist portrayal of decision-making within the Guatemalan forestry sector.

effects governance structure on forest cover change in the context of high pressure for development and deforestation at the municipal level. This is exactly the test we conduct in the next section.

## **5 Empirical Strategy**

The major empirical contribution of the study is to rigorously evaluate a key hypothesis about forest cover change drawn from polycentric governance theory, namely that higher levels of polycentricity within governance systems will be associated with better forest outcomes. We argue that the clearest test of whether polycentric governance can actually have this effect is by examining outcomes where there is a clear pressure toward deforestation. In short, we don't believe that the cases where it is costless to leave forests standing are particularly informative with respect to the effects of governance structure and institutional arrangements. Therefore, we focus specifically on the key dynamic generating incentives to deforest in Guatemala – the increasing importance of agricultural development for some municipalities – and test whether the level of polycentricity within the governance system can moderate the incentives faced by municipal authorities under these circumstances.

We utilize a longitudinal dataset on forestry and institutions for 100 municipalities in Guatemala to examine the drivers of change in forest cover transformation over time. Specifically, we analyze three sources of data: (1) surveys with key forestry governance actors, (2) national census data, and (3) biophysical indicators derived from satellite imagery. First, researchers collected survey data for a representative sample of 100 municipalities in Guatemala in 2001 and 2007. Survey staff administered a questionnaire to the mayor in each municipality during the first wave data collection (2001), and in the second wave (2007) they surveyed the

mayor of each municipality, the president of the local water committee and the president of the development council, and a representative from the municipal forestry office. They collected data on policy priorities, relationships among different actors in the municipality, management challenges, citizen participation, and forestry governance.<sup>3</sup> Researchers checked a subset of survey responses against archival data and found the survey instruments to be highly reliable (Andersson et al. 2010). Second, the staff compiled national census data and data from municipal archives on local-level characteristics and socio-economic conditions. And third, colleagues generated data on forest cover, deforestation, land topography, and road density for each municipality from satellite imagery using remote sensing techniques. The resulting dataset, combining socio-economic information, two waves of surveys with mayors and other local actors, and biophysical data over twenty years represents the most comprehensive information available for evaluating the drivers of forest change in Guatemala. In the following sections we detail the dependent and independent variables utilized in this study and present our analysis.

## **5.1 Dependent Variable**

### *Difference in annual forest cover change, 2001-2006 to 2006-2010*

Forest cover change variables were created from satellite imagery using remote-sensing techniques for three overlapping time periods: 1991-2001 (period 1), 2001-2006 (period 2), and 2006-2010 (period 3). For all three periods, researchers calculated the annual rate of forest change for each municipality in Guatemala; these variables can range from zero to one with positive values representing annual increases in forest cover as a proportion of total forested area in the municipality, and negative values representing rates of deforestation. Figure 1 below

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<sup>3</sup> We include the translated text of selected survey questions in Appendix A.

presents histograms of the annual rates of change in forest cover for all three periods. We treat the first period, 1991-2001, as a lag dependent variable in the analysis and take the difference in the rate of forest cover change between periods two and three as the primary dependent variable for this study. Accordingly, our goal is to explain the change in the rate forest cover change between 2001-2006 and 2006-2010; positive values indicate an improvement in the annual rate of forest cover change, either reforestation or slowing deforestation in period three relative to period two, while negative values represent worsening environmental outcomes in the form of deforestation or slowing reforestation over the two periods. Panel four in figure 2 presents the full distribution for the differenced forest cover change variable.

The satellite imagery and the remote-sensing techniques used to create the forest cover change variables generate both uncertainty and measurement error, and the final differenced variable includes significant outliers. Therefore, we choose to reduce the raw differenced forest cover change variable into four categories: significant deforestation (1), moderate deforestation (2), neutral to slight reforestation (3), and moderate reforestation (4). These four categories correspond to the quartiles of the distribution of the differenced forest cover change variable. Figure 3 below presents the differenced forest cover change variable with its quartile categorization. We implement the same procedure for categorizing forest cover change between 1991 and 2001 for inclusion as lag dependent variable in the regression analysis.

Figure 2: Annual Rates of Change in Forest Cover for Three Overlapping Periods between 1991 and 2010

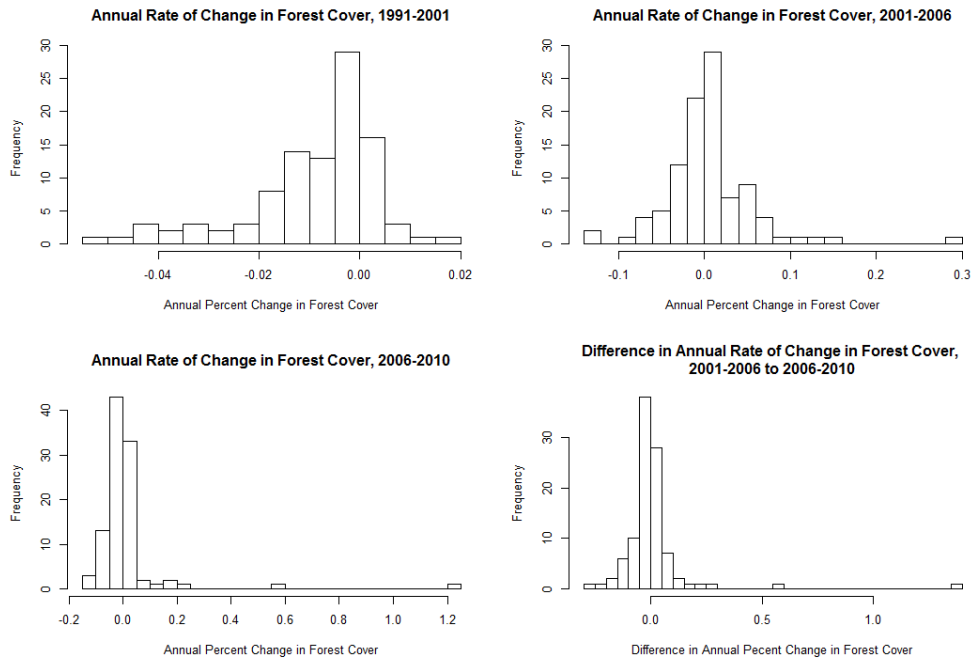
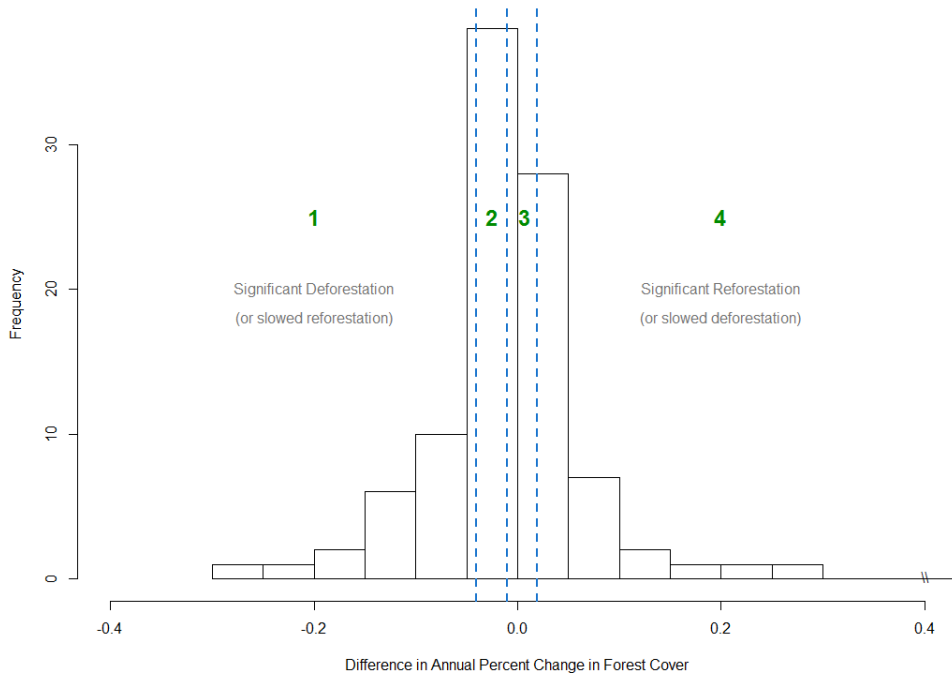


Figure 3: Categorized Difference in Rate of Change in Forest Cover, 2001-2006 to 2006-2010



## 5.2 Independent Variables

In the following sections we describe the independent variables included in our ordered logistic regression analysis of the drivers of forest cover change in Guatemala. These data were largely collected through surveys with mayors in 2001 and 2007. Temporally, we expect that institutional, socio-economic, and personal attributes reported in 2001 will be associated with subsequent forest outcomes during the 2001-2006, while attributes reported in 2007 will be associated with forest outcomes during the 2006-2010. Where appropriate, we calculate the difference in the value of the independent variables between 2001 and 2007 as a strategy for explaining the difference in the annual rate of forest change between 2001-2006 and 2006-2010.<sup>4</sup>

Table 1 presents descriptive statistics for all independent variables utilized in the analysis.

Table 1: Descriptive Statistics for Selected Independent Variables

	N	Mean	St. Dev.	Min	Max
<b>Forest Change</b>					
Annual Forest Change, '91-'01	100	-0.009	0.013	-0.054	0.018
Diff. in Annual Forest Change, '01-'06 to '06-'10	100	0.006	0.167	-0.256	1.372
<b>Polycentric Governance</b>					
Δ Polycentricity, '01-'07	99	0.039	0.208	-0.707	0.373
Δ Importance of Agriculture, '01-'07	96	0.240	2.214	-4	4
<b>Mayor Attributes</b>					
Δ Age of Mayor, '01-'07	98	1.194	11.733	-31	32
Δ Years Holding Office, '01-'07	95	0.191	3.565	-8.000	8.500
Δ Years of Schooling, '01-'07	92	0.511	5.916	-15	13
<b>Municipality Attributes</b>					
Δ Autonomy, '01-'07	94	0.229	1.569	-4.667	3.333
Δ Importance of Forestry, '01-'07	96	0.173	1.538	-5.536	3.286
Δ No. of Community Organizations, '01-'07	99	-0.091	1.254	-4	3
Δ Approp. Balance of Control in Forestry, '01-'07	96	-0.104	1.786	-5	4
<b>Control Variables</b>					
Proportion of Municipality Forested, '01	99	0.279	0.305	0.004	2.002
Proportion of Municipality Forested (log), '01	99	-1.809	1.185	-5.417	0.694
Income per Capita, '97	100	33.321	26.762	1.263	154.138
Income per Capita (log), '97	100	3.254	0.746	0.234	5.038
Average Slope	99	13.218	6.049	0.850	25.570
Density of Roads	98	14.512	5.296	2.458	30.783

<sup>4</sup> The first difference estimator for a two time-period panel data structure is equivalent to the fixed effects estimator (Wooldridge 2002, 284).



### **5.2.1 Polycentricity and Incentives to Deforest**

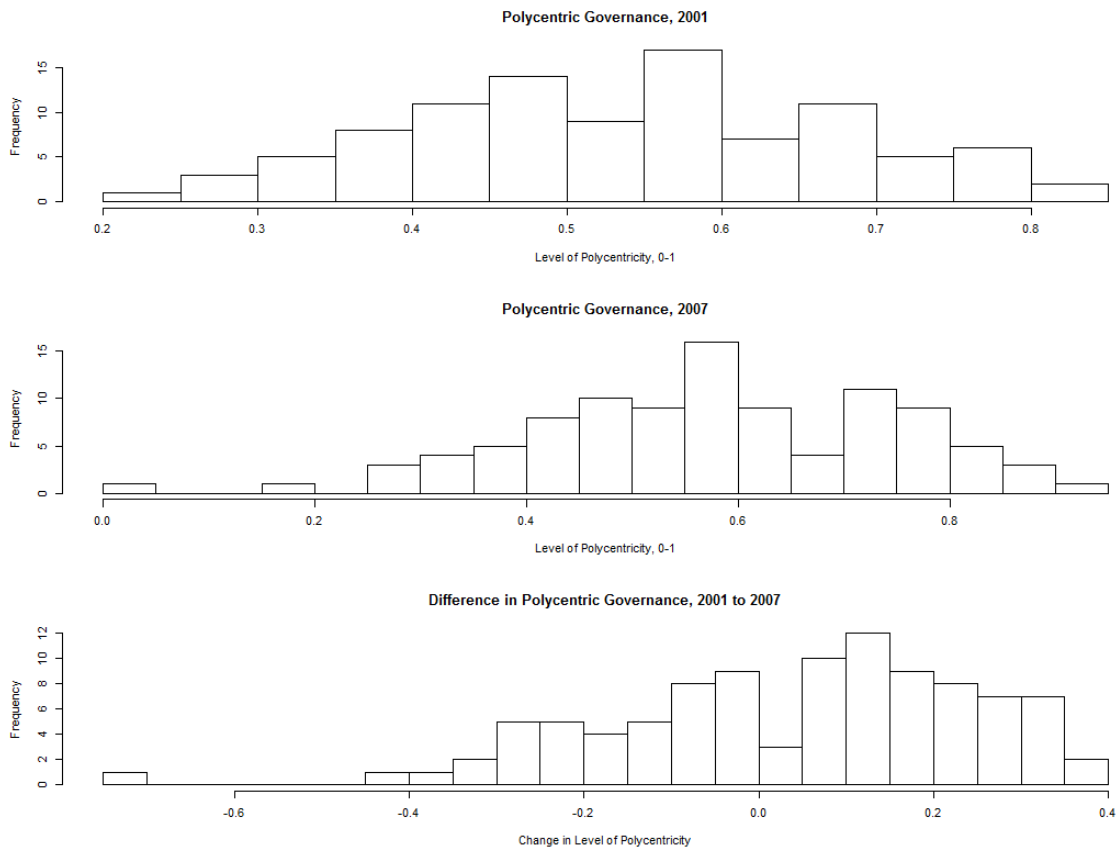
#### *Change in polycentricity, 2001-2007*

Polycentricity within a governance system is fundamentally about the degree to which relevant actors across levels of government are connected to one another and can act independently or in collaboration within overlapping arenas. Four key types of actors are involved in the Guatemalan forestry sector: local community organizations, municipal councils, NGOs and other external or regional agencies, and the national government. Therefore, we operationalize the degree of polycentricity at the municipal level using a scaled score calculated from five survey questions related to connections between the mayor and the other three types of organizations.

First, with respect to local community organizations, researchers asked mayors to report the frequency with which those groups expressed their opinions on forestry using a five-point scale. Second, for NGOs and other external or regional organizations, mayors reported the frequency with which they expressed their opinions on forestry and the importance of financial transfers from these groups for the municipality, both on a five-point scale. And third, mayors responded to two questions about the central government, first reporting the number of central government agencies that regularly cooperate with the municipal council (converted to a five-point scale), and then indicating the importance of transfers from the central government as an income source for the municipality on a five-point scale. Each municipality received a composite score for these five questions in both 2001 and 2007, which was converted to a proportion out of the maximum score of 25. Finally, we subtract the 2001 score from the 2007 score to produce a differenced variable representing the change in level of polycentricity between the two periods. Positive values on this variable represent increased levels of

polycentricity in the governance system over time while negative values indicate lower polycentricity. Figure 4 below presents the 2001, 2007, and differenced polycentric governance variables.

Figure 4: Levels of Polycentricity in Municipal Forestry Governance Systems, 2001-2007



*Change in importance of agriculture, 2001-2007*

Maintaining land in its forested state or converting that land to agriculture uses is one of the major tradeoffs faced by mayors and municipal councils in Guatemala. The pressure for agricultural development, and the potential income for both local citizens and the municipal council from that type of land use, is a major incentive for deforestation. To characterize the relevance of this pressure, forestry officials responded to a survey question asking how

significant the contribution of agriculture is to municipal finances on a five-point scale, with higher values indicating agriculture is more important than other sectors. The difference on this variable between 2001 and 2007 represents the change in the importance of agriculture within the municipality over the two periods.

### **5.2.2 Mayor Attributes**

#### *Change in age, 2001-2007*

Mayors reported their age at the time of the survey in 2001 and 2007. The difference in age of the mayor across the two time periods reflects how much older or younger the more recent mayor is relative to the past mayor.

#### *Change in years holding office, 2001-2007*

Mayors surveyed in 2001 and 2007 reported the number of years they had held office; we take the difference in the value of this variable across the two periods as an indication of the change in governing experience of the individual leading the municipal council. Higher values indicate mayors who have held office longer and who have likely been re-elected to their posts during the time between the periods, whereas lower values will be associated with less experienced and newer politicians in their current positions.

#### *Change in years of schooling, 2001-2007*

Mayors in both survey waves also reported the number of years of formal schooling they had completed, with higher values indicating more education. The change in the value of this variable between 2001 and 2007 reflects how much more or less educated the individual holding the office was in 2007 was relative to the mayor in 2001.

### **5.2.3 Municipality Attributes**

#### *Change in autonomy, 2001-2007*

Following Andersson et al. (2010), we use the importance of local tax revenues for the municipal government as an indicator of its autonomy from the central government and a proxy for local capacity. When mayors report that local taxes are an important income source this implies that municipal institutions are strong enough to collect taxes and that the municipal council has additional funds it can allocate above and beyond the transfers it receives from the central government. In the context of local governments in developing countries, this is an important indicator of autonomy and capacity. We construct this variable as the average reported importance for the municipality of local taxes on individuals and businesses and income from property rental minus the reported importance of transfers from the central government (all on five-point scales). In both 2001 and 2007, this variable represents the relative importance of local income sources for the municipality, with higher values indicating local taxes are more important than transfers from the central government. Higher values on the differenced variable between 2001 and 2007 reflect municipalities where local income streams become more important over time.

#### *Change in importance of forestry, 2001-2007*

We measure the level of priority that the mayor places on forestry in the municipality based on questions asking him or her to characterize the importance of municipal activities associated with providing ten types of public services on a five-point scale. For both 2001 and 2007, we construct this variable as the rating for forestry activities minus the average rating for the other types of public services, with negative values indicating that forestry activities are less

important than other public services and positive values indicating that forestry activities are more important. We then calculate the difference in the value of this variable for each municipality from 2001 to 2007; positive values are indicative of municipalities where forestry activities become more important over time, while negative values reflect decreasing importance of forestry.

*Change in number of community organizations, 2001-2007*

Mayors responded to a survey question asking them to characterize how the number of community organizations in the municipality changed during their terms on a five-point scale. The difference in the value reported between 2001 and 2007 reflects the changing presence of community organizations from the perspective of the municipal council; positive values indicate increasing growth in the number of community organizations working in the municipality over time, while negative values reflect circumstances where the number of organizations has declined at an increasing rate between the two periods.

*Change in appropriate balance of central versus municipal control in forestry, 2001-2007*

This variable characterizes the expressed opinion on forestry decentralization by mayors, specifically their view of the appropriate balance of control between the central government and the municipal government in the forestry sector. Using a five-point scale, survey staff asked mayors to report their opinion on decentralization across eleven policy arenas. In order to isolate mayors' opinions on forestry decentralization relative to their views on decentralization in general, we construct this variable as the forestry decentralization rating minus the average rating across all other public services. Positive values indicate that the mayor feels relatively more municipal control is appropriate with respect to forestry as compared to other public services,

while negative values indicate the mayor favors central government control of forestry. The difference in the relative values in 2001 and 2007 reflects the degree to which mayors have increased or decreased their preference for municipal control in forestry management over time.

#### **5.2.4 Biophysical and economic control variables**

##### *Proportion of municipality forested, 2001 (log)*

In addition to the stated importance of forestry, the actual proportion of land containing forests within the municipality is an indication of how relevant forestry and forest management are to the municipal council. Researchers constructed this variable to reflect the total proportion of all land area in the municipality that is covered by forests in 2001 based on satellite imagery. We take the log of this variable to address its severely skewed distribution and significant outliers.

##### *Income per capita, 1997 (log)*

Income data are notoriously unreliable in developing countries, especially when disaggregated to the municipal or local level. We use income per capita figures calculated by Andersson and colleagues based on data they compiled from reports by the Central American Development Foundation in 1997. This is clearly an imperfect measure of the overall well-being, though arguably more reliable than national census data. The distribution of the municipal income data is highly skewed, and therefore we follow the convention in the political economy literature and log-transform this variable.

##### *Slope*

Researchers also calculated the average slope for each municipality. This variable

reflects how steep or how flat the overall landscape is in each municipality. Higher values reflect steeper terrain which is less suitable for agriculture and other types of development.

#### *Road density*

The road density variable, also calculated from satellite imagery, characterizes the length of paved roads in each municipality per unit of area. This variable serves as an alternative proxy for the overall level of development in each municipality.

### **5.3 Analyzing Forest Cover Change and Testing Polycentric Governance Theory**

We implement ordered logistic regression, a generalized linear model for dependent variables that are ordered categories, to analyze the drivers of forest change in Guatemala across two time periods. Our overall approach is to model the categorized change in the annual rate of forest cover change between 2001-2006 and 2006-2010 using differenced independent variables corresponding to the beginning of those time periods, as well as time-invariant covariates. In the context of analyzing the factors associated with forest cover change, our primary goal is to test the hypothesis that higher levels of polycentricity in the governance of social-ecological systems will be associated with better environmental outcomes. With respect to forestry in Guatemala, we argue that testing this hypothesis must take into consideration the explicit trade-offs between agriculture and forests made by municipal decision-makers. Therefore, we include an interaction term in all models between the change in the level of polycentricity and the change in the importance of agriculture at the municipal level. If polycentric governance is to have a substantive effect on forest outcomes, this effect needs to manifest itself where there are real costs to preserving forests, namely where the pressure to develop land for agriculture is highest.

Accordingly, our primary hypothesis implies that the interaction of polycentricity and the importance of agriculture will be significant with a positive sign suggesting that increases in polycentricity moderate the negative pressure of increasing agricultural importance on forest cover change. More plainly, evidence consistent with our hypothesis would show that municipalities that more strongly connected to local, regional, and national actors are less likely to deforest under high pressures for agricultural development relative to municipalities with weaker connections to external actors across levels of government.

Table 2 below presents five ordered logistic regression models of forest change for 100 municipalities in Guatemala. The first model serves as a baseline by including only past forest change and the interaction of polycentricity and agricultural importance. The subsequent models add different sets of independent variables drawn from the literature on decentralization and forestry as well as biophysical and economic control variables. The interaction of polycentricity and agricultural importance is positive and significant in four of the five models, providing tentative support for our primary hypothesis.



Table 2: Understanding the Drivers of Forest Cover Change in Guatemala using Ordered Logistic Regression Analysis, 2001-2006 to 2006-2010

	<i>Dependent variable:</i>				
	Difference in Annual Rate of Forest Change, Four Categories				
	(1)	(2)	(3)	(4)	(5)
<b>Past Forest Change</b>					
Annual Forest $\Delta$ , '91-'01	-0.351** (0.176)	-0.278 (0.189)	-0.291 (0.211)	-0.334 (0.205)	-0.234 (0.227)
<b>Polycentric Governance</b>					
$\Delta$ Polycentricity, '01-'07	-0.533 (0.977)	-0.930 (1.137)	-0.272 (1.278)	-0.434 (1.266)	-0.973 (1.506)
$\Delta$ Importance of Agriculture, '01-'07	-0.128 (0.086)	-0.156* (0.092)	-0.159 (0.103)	-0.149 (0.101)	-0.203* (0.110)
$\Delta$ Polycentricity * $\Delta$ Importance Agriculture	0.580 (0.376)	0.899** (0.444)	1.071** (0.497)	1.075** (0.496)	1.028* (0.547)
<b>Mayor Attributes</b>					
$\Delta$ Age of Mayor, '01-'07		-0.0001 (0.021)	0.008 (0.023)	0.006 (0.023)	0.005 (0.027)
$\Delta$ Years Holding Office, '01-'07		0.028 (0.061)	0.084 (0.064)	0.085 (0.064)	0.118 (0.075)
$\Delta$ Years of Schooling, '01-'07		0.014 (0.040)	0.018 (0.042)	0.010 (0.041)	0.052 (0.047)
<b>Municipality Attributes</b>					
$\Delta$ Autonomy, '01-'07			0.176 (0.148)	0.132 (0.144)	0.321* (0.169)
$\Delta$ Importance of Forestry, '01-'07			-0.171 (0.157)	-0.149 (0.156)	-0.252 (0.171)
$\Delta$ No. of Community Organizations, '01-'07					-0.088 (0.203)
$\Delta$ Approp. Balance of Control in Forestry, '01-'07					-0.280* (0.146)
<b>Control Variables</b>					
Proportion of Municipality Forested (log), '01			-0.032 (0.202)		-0.153 (0.282)
Income per Capita (log), '97					-0.086 (0.306)
Average Slope					0.045 (0.049)
Density of Roads					-0.056 (0.048)
Observations	95	85	78	79	74
AIC	267.34	244.60	228.35	229.43	222.73
BIC	285.21	269.03	258.98	257.86	264.20
Log Likelihood	-126.67	-112.30	-101.17	-102.71	-93.36

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

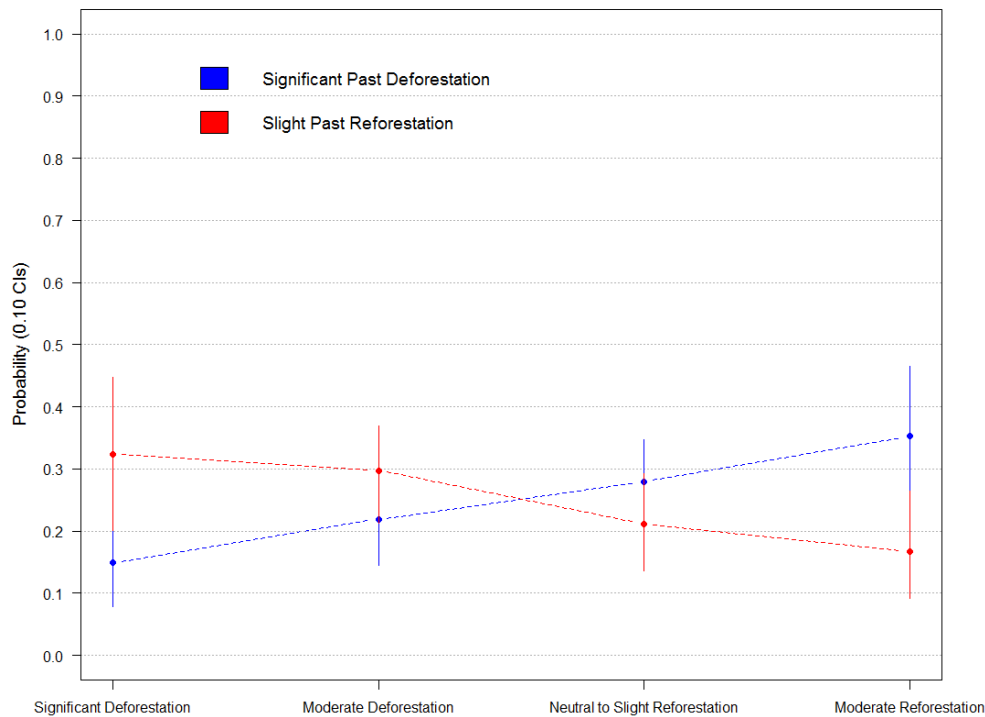
Overall, we draw three main conclusions from this set of models. First, past forest change is only significant in the baseline model and loses its significance when additional independent and control variables are included. This suggests that past levels of forest change

are not as important to current forest cover transformation in Guatemala as conventionally thought. Moreover, past forest cover change has a negative sign in all models indicating that better past forest outcomes will actually decrease the probability of better current forest outcomes. Figure 5 below presents predicted probabilities of a municipality being in each of the four categories of current forest cover change from model 1 based on having had significant deforestation or slight reforestation during the 1991-2001 period.<sup>5</sup> The significant coefficient on past forest change from model 1 does not translate into substantive differences in current forest outcomes. Slight past reforestation does decrease the probability of better current forest outcomes, and significant past deforestation increases that probability – suggesting that it is easier to improve outcomes currently if they were especially bad in the past and harder to maintain improvement over time – but the two groups are not substantially different over the range of categories. This is actually a fairly optimistic null finding. It appears that current mayors are not entirely constrained by the history of forest management, good or bad, in their municipalities; this suggests that decisions and actions they take today can make a difference for the forests under their supervision.

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<sup>5</sup> The 0.10 confidence intervals on these quantities of interest are calculated with the Zelig package in R using 10,000 simulations (Imai et al., 2006).

Figure 5: Current Annual Forest Change by Past Forest Change

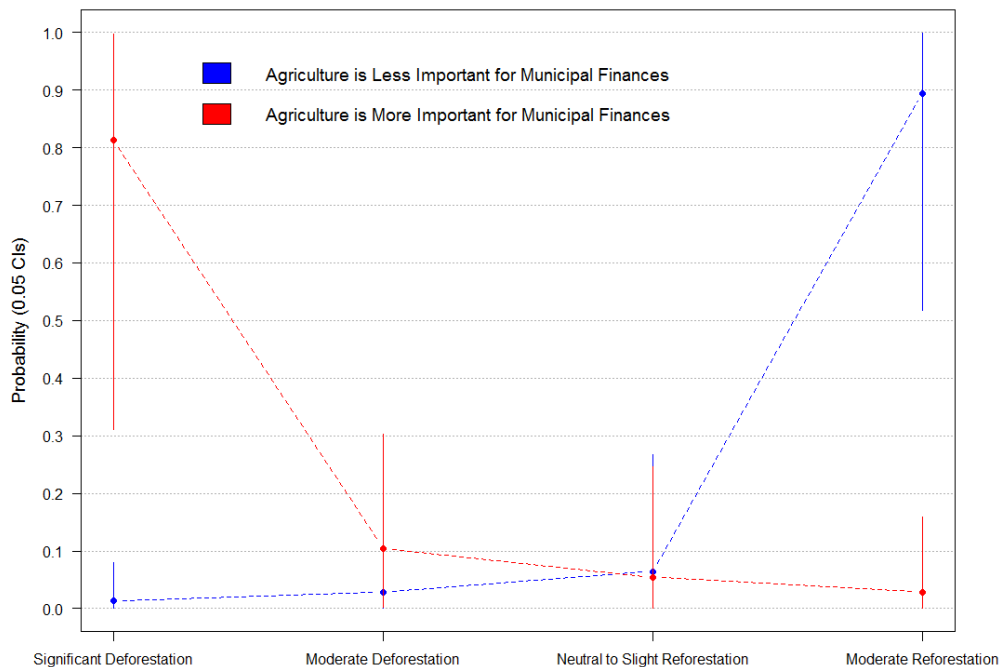


Second, under our change score modeling strategy with the differenced independent variables we employ, the factors commonly thought to be associated with forestry outcomes are largely insignificant across our model specifications. Changes in the attributes of the mayor and biophysical and economic control variables do not appear to have any significant association with changes in annual rates of forest cover transformation in Guatemala. Municipal attributes are also largely insignificant across model specifications, though local autonomy (or capacity) and the mayor’s opinion on the appropriate balance of control between the local and central authorities in forestry are weakly significant in the final model.

Third, and most importantly, higher polycentricity in the governance system does appear to moderate the pressure for deforestation from agriculture in a substantively important way. We present the moderating relationship between polycentricity and the importance of agriculture on

forest cover change using two scenarios, displayed in figures 6 and 7 below, with estimates based on the specification in model 4.<sup>6</sup> Figure 6 presents the predicted probability that a municipality falls in each of the four categories of recent annual forest cover change in the context of a large decrease in polycentricity, both when agriculture has become more important and when it has become less important. Under this scenario, the importance of agriculture drives forestry outcomes. Namely, when agriculture has become less important to the municipality, and thus the cost of leaving forests standing is relatively low, municipalities are much more likely to be in the moderate reforestation category. However, when agriculture becomes more important, and there is a tangible cost to avoiding deforestation, municipalities largely appear unwilling to pay that cost and are much more likely to be in the significant deforestation category.

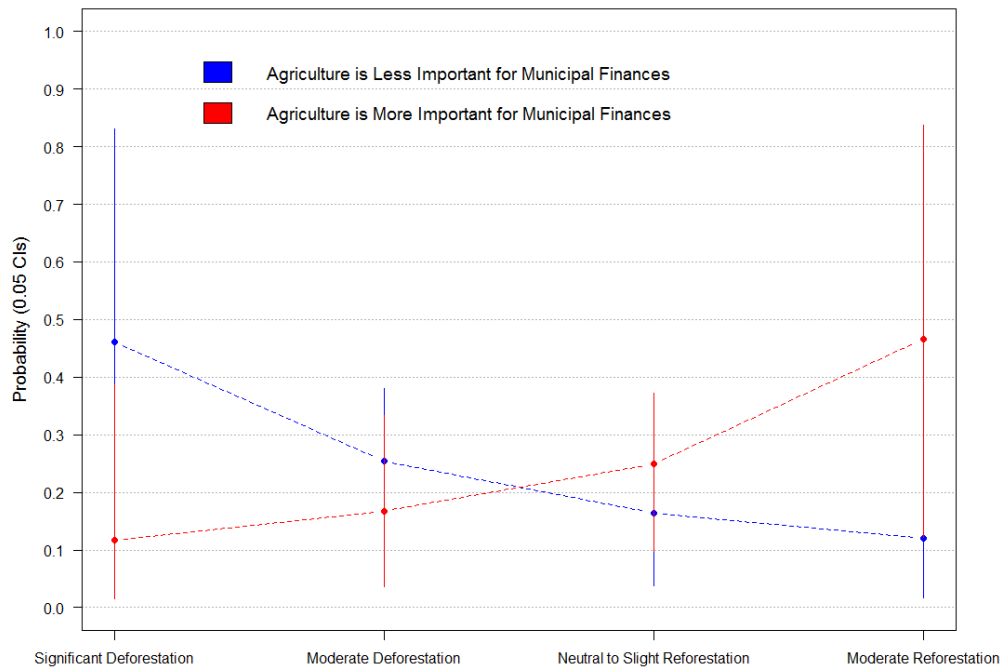
Figure 6: Annual Forest Change by Importance of Agriculture under a **Large Decrease** in Polycentricity (2001 to 2007)



<sup>6</sup> We select model 4 for this presentation because it best fits the data using the Bayesian information criterion as a gauge for model fit. As previously, the 0.05 confidence intervals on the quantities of interest presented in figures 6 and 7 are calculated with the Zelig package in R using 10,000 simulations (Imai et al., 2006).

Figure 7 presents the same scenario of forest cover change in the face of agriculture becoming more and less important for the municipality, but this time in the context of a large increase in polycentricity over the two periods. Here, a substantively different story emerges. Moderate reforestation is now more likely when agriculture is important for the municipality and less likely when it is not, the exact opposite of the relationship under a large decrease in polycentricity. The inverse also holds for significant deforestation: municipalities where agriculture has become less important are now actually more likely to be in the significant deforestation category than those where agriculture has become more important. Most importantly, however, is the fact that the two extremes of agricultural importance are no longer statistically distinguishable in their effects on forest cover change. This suggests that a large increase in polycentric governance may be able to diminish or counter-balance the pressure that increasing importance of agriculture has in spurring deforestation over the same period. The confidence bounds on the point estimates are quite large given our small sample size, but this analysis nonetheless provides preliminary evidence that increases in the level of polycentricity within a governance system are associated with better forestry outcomes, and that this positive influence of governance structure is most pivotal precisely when incentives to deforest are greatest.

Figure 7: Annual Forest Change by Importance of Agriculture under a **Large Increase** in Polycentricity (2001 to 2007)



## 5.4 Limitations

Survey data are notoriously plagued by missing observations, and this problem is especially acute given the small representative sample of municipalities in the present study. In short, the models presented in table 2 suffer significantly from missing data problems. Table 1 shows that the amount of missingness on any one variable is relatively low with the worst case having eight missing observations and most being between two and four. The missing data problem is compounded, however, as we add variables to the baseline model, with the total number of observations dropping precipitously between models two and five. This is actually somewhat reassuring that the missingness could be random – rather than missing all data for a few municipalities, we face the case of small amounts of missingness throughout the dataset. If the missingness is in fact random, then case-wise deletion (the default approach for dealing with

missing data in most statistical packages) will result in estimates that are inefficient but not necessarily biased. If the missingness is not random, then the models presented would be producing biased estimates. As a result, our findings and conclusions must be considered tentative and preliminary.

The small amount of missing data we face throughout the dataset is an appropriate circumstance for using multiple imputation techniques to estimate the missing values based on the existing data. We will implement this strategy and re-estimate the models presented here in the next version of this paper.

## **6 Conclusions**

In this study we undertake a systematic and rigorous analysis of the drivers of forest cover change at the subnational level in Guatemala under a single decentralization policy that is uniformly applied across the country. This case allows us to examine the factors that affect local variation in forestry outcomes within the context of a consistent environment of decentralization. Mostly importantly, the overall study is presented as a test of polycentric governance theory, the idea that the strength of connections among actors across levels of government will matter for tangible policy outcomes. With respect to forestry in Guatemala, we hypothesize that greater levels of polycentricity within forestry governance systems anchored at the municipal level will be associated with positive changes in forest cover. Furthermore, we argue that a relevant test of this theory needs to consider incentives in favor of deforestation at the municipal level and examine the effects of governance structure precisely where those incentives are strongest. The quantitative analysis of longitudinal data on forests and institutions implements this very test by

evaluating the interactive effects of polycentricity and the importance of agriculture on forest cover change using ordered logistic regression models.

Two important conclusions about polycentricity and forest cover change emerge from our analysis. First, past forest cover change does not appear to be a significant and substantively important driver of current forest cover change. This is actually a very positive null finding from the perspective of policymakers: municipal governments do not appear to be overly constrained by their histories of deforestation, and the decisions they take today can have an effect on outcomes in the relatively short-term. Second, our evidence suggests that positive changes in polycentricity can counteract the pressures towards deforestation where agriculture is increasingly important for the finances of a municipality. When the degree of polycentricity decreases over time within a municipality, the pressure for agriculture drives negative forest cover change, but where there are increases in polycentricity the high and low cases of agricultural pressure on forests are indistinguishable. This is a second optimistic finding for policymakers as it suggests that institutional structures may be able to moderate and minimize the incentives prompting deforestation in developing countries.



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## 8 Appendix A

Table 3: Survey Questions for Selected Independent Variables

Variable	Questions	Responses
Polycentricity	List the number of central government organizations/agencies that cooperate with the municipal government on its top priority.	0, 1, 2, or 3 (scaled 0-5)
	How important were central government transfers as an income source for the municipality during the last term?	5 – much more important than other income sources 4 – more important than other income sources 3 – as important as other income sources 2 – less important than other income sources
	How important were transfers from external actors (like NGOs, projects, or assistance) as an income source for the municipality during the last term?	1 – much less important than other income sources 5 – very frequently 4 – frequently
	With what frequency did NGOs express their opinions on forestry during the last term?	3 – sometimes 2 – occasionally 1 – never
	With what frequency did community organizations express their opinions on forestry during the last term?	
Importance of Agriculture	How significant has the contribution of agriculture been to the public finances of the municipality during your term? (asked of forestry officials)	5 – much more important than other sectors for the municipal finances 4 – more important than other sectors for the municipal finances 3 – as important as other sectors for the municipal finances 2 – less important than other sectors for the municipal finances 1 – much less important than other sectors for the municipal finances
Age of Mayor	How old are you? (asked of mayors)	Number of years
Years Holding Office	For how much time have you been mayor?	Number of years
Years of Schooling	How many years of school did you complete? (asked of mayors)	Number of years
Autonomy	How important were the following income sources for the municipality?	5 – much more important than other sources
	<ul style="list-style-type: none"> <li>• Local taxes on individuals</li> <li>• Local taxes on business</li> <li>• Rental income from municipal property</li> <li>• Transfers from the central government</li> </ul>	4 – more important than other sources 3 – almost same importance as other sources 2 – less important than other sources 1 – much less important than other sources

Importance of Forestry	<p>How important were the following activities during your term? (asked of mayors)</p> <ul style="list-style-type: none"> <li>• Trash collection</li> <li>• Sewers</li> <li>• Potable water</li> <li>• Electricity</li> <li>• Roads</li> <li>• Public security</li> <li>• Forestry</li> <li>• Agricultural sector</li> <li>• Health</li> <li>• Education</li> </ul>	<p>5 – much more important than other activities  4 – more important than other activities  3 – as important as other activities  2 – less important than other activities  1 – much less important than other activities</p>
No. of Community Organizations	<p>Did the number of community organizations change during your term? (asked of mayors)</p>	<p>5 – increased in an important way  4 – increased  3 – did not change  2 – decreased  1 – decreased in an important way</p>
Appropriate Balance of Control in Forestry	<p>What is the appropriate balance of control between the municipal government and the central government in forestry? (asked of mayors)</p> <ul style="list-style-type: none"> <li>• Trash collection</li> <li>• Sewers</li> <li>• Potable water</li> <li>• Electricity</li> <li>• Roads</li> <li>• Public security</li> <li>• Forestry</li> <li>• Environmental sector</li> <li>• Health</li> <li>• Agriculture</li> <li>• Education</li> </ul>	<p>5 – very high control by municipal government, very little control by central government  4 – high control by municipal government, occasionally control by central government  3 – same level of control by municipal government and central government  2 – occasional control by municipal government, high control by central government  1 – little control by municipal government, very high control by central government</p>