

WHY IS FOREST LOST?

A MULTI-SCALE STUDY OF FOREST COVER CHANGE IN
GUATEMALA

MAJA STADE AARØNÆS

NORWEGIAN UNIVERSITY OF LIFE SCIENCES
DEPARTMENT OF ECOLOGY AND NATURAL RESOURCE MANAGEMENT
MASTER THESIS 30 CREDITS 2010



Preface

This Master's thesis represents the final project for receiving the Master's degree in Natural Resource Management at the Norwegian University of Life Sciences (UMB), department of Ecology and Natural Resource Management.

First of all I want to thank my three supervisors: Stein R. Moe (main supervisor), Mariel Aguilar Støen, and Edwin J. Castellanos for helpful council and facilitation of this thesis. I also want to thank all of the great staff at Centro de Estudios Ambientales at Universidad del Valle de Guatemala. They welcomed me with open arms and were happy to help answer all my questions and cover all my needs. I further want to thank all the people who I met during my stay in Guatemala, and who gave me their views on topics relevant for this thesis. I am amazed how all of them met me with wonderful patience despite my limited language skills. And I especially want to thank Doris Martínez; who opened her home to me, introduced me to city, and supported me in all possible ways throughout my stay.

Thanks to my great friends; Cathrine, Farshad, Kristine, Linn, and Svein, for their comments and proof-reading during the final week.

A special thanks goes to my family and friends for supporting me and believing in my in all my doings. And last, but not least, I want to thank everyone that has made my time at Ås to a great adventure from the first day until today.

Maja Stade Aarønæs, Ås, 19.08.2010

Abstract

In order to halt deforestation rates and manage existing forest areas efficiently, the causes behind forest cover change must be identified and the dynamics understood. This study aims to contribute to the field with exploring potential causes behind forest cover change in Guatemala. Guatemala experienced high deforestation rates throughout the time of the study with an annual net loss of 1.43% of the forested area.

This study analyzed forest cover change in Guatemala between 1993-94 and 2001 in relation to sixteen variables potentially influencing forest dynamics. A meta-analysis approach was employed in order to explore the potential relationships and indicate to what degree the included variables explain the observed spatial variation in forest cover change. The variables included demographical, economical, physical and institutional aspects at three levels, ranging from the local municipality level, to the department and region level. Statistical procedures and qualitative investigations were used to investigate the associations.

The findings of this study support the findings of previous studies that causes behind forest cover change are complex, context dependent, and site specific. Explicit cause-effect relationships explaining forest cover change across all three levels were not distinguished, but trends acting on the different scales were observed. The findings revealed higher deforestation in areas with low initial forest cover, contradictory to the general conclusion from the literature. Moreover, four variables were identified to have a distinct link to low deforestation; (i) high proportion of urban population, (ii) high densities of paved road, (iii) low extreme poverty levels, and (iv) low proportion of the economically active population working in agriculture. These four variables can all be linked to development, and the findings may indicate that the country is undergoing forest transition that over time will lead to a halt in deforestation rates and eventually reforestation. Even if the current deforestation rates are high, the observed trends may be one of the first signs of a beginning transition. This is a promising prospect for the future of the forests in Guatemala, but the conclusion needs additional research and more complex methods for exploration in order to verify these findings further.

Table of Contents

Introduction	1
Study site.....	2
Potential variables causing forest cover change in Guatemala.....	6
Methods.....	12
Potential variables driving forest cover change in Guatemala	14
Qualitative analysis	16
Statistical analysis	16
Results.....	18
Region	18
Department.....	19
Municipality	23
Discussion.....	26
Region	27
Department.....	28
Municipality	28
Potential explanatory variables causing forest cover change	29
Other variables with potential effect.....	37
Additional observations	39
Conclusion.....	40
Literature list.....	42
Appendices.....	58
Appendix 1. Correlated explanatory variables at department level.....	58
Appendix 2. Correlated explanatory variables at municipality level	59

Introduction

Nearly one third of the world's terrestrial land mass is covered by forests (FAO, 2000), and the forest contributes with services and products of high importance for humans. Ecosystem services originating from forest includes provision of food, fuel, feed and fiber for consumption, and benefits like habitats for biological diversity, climate regulation, and soil and water conservation. Forests are further valued as cultural heritage, and provide sites for education, recreation, and research (Pearce and Brown, 1994; Chomitz, 2007; Parrotta et al., 2007; Bond et al., 2009).

Forests experience augmented pressure from a diverse array of stakeholders, directly as demand for forest resources, and indirectly as demand for land for agricultural production, pasture, and human settlements (Barbier et al., 2010). The Food and Agriculture Organization of the United Nations (FAO) (2006) estimated global deforestation rates at 0.22 % in the 1990s, a combination of 14.6 million hectare deforestation and 5.2 million hectare reforestation, resulting in 9.4 million ha net forest loss.

To halt deforestation rates, forest conservation and reforestation has been increasingly promoted. The negotiations around the Kyoto-protocol and the UN Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD programme) are examples of global initiatives concerning forest issues. In order to reverse the negative trends in forest dynamics, causes behind the changes must be identified, and relevant measures to manage them must be implemented (Honey-Rosés, 2009; Rudel et al., 2009).

Deforestation is an important issue in Guatemala, the country that once derived its name from the word "Quauhtemalan" in Náhuatl meaning "the land of trees" or "the forest place" (Melgar, 2003).

Deforestation has been an issue throughout the colonial period and after independence, mainly caused by agricultural expansion into forested areas as means to promote economic development (Melgar, 2003). In the last part of the 20th century deforestation rates have increased further, reducing forest cover in Guatemala from 67% in the 1950s to 40% by 2003 (Universidad Rafael Landívar et al., 2009).

The responsibility for forest management in Guatemala is divided between two institutions: the National Forestry Institute (Instituto Nacional de Bosques, INAB), which is responsible for the administrative and operational management of the forest outside protected areas, and the National Council for Protected Areas (Consejo Nacional de Áreas Protegidas, CONAP) with the authority and management responsibility

for protected areas, including the forest. The National Forestry Institute replaced the weaker and more politically controlled forest management institution, The General Directorate of Forestry (Dirección General de Bosque, DIGEBOS) in 1996 (Jones, 1990; Ferroukhi, 2003; Melgar, 2003; INAB, 2006).

The research of the causes behind deforestation has over time changed from focusing on one or a few general drivers to a complex mixture of context dependent causes that are specific for each site and situation (e.g. Kaimowitz, 1997; Kaimowitz and Angelsen, 1998; Contreras-Hermosilla, 2000; Lambin et al., 2003; Ewers, 2006).

This study aims to identify the key drivers causing different rates of forest cover change in Guatemala. Qualitative and quantitative information is utilized in order to explore possible relevant variables causing deforestation. A range of variables covering demographical, economical, physical and institutional aspects are analyzed to assess to what degree they explain the observed spatial variation in deforestation rates. The analysis identifies the effect of these variables on different scales, ranging from the local municipality level, to the department and region level, which enables a comprehensive evaluation of the dynamics.

The thesis is written in the format of a scientific paper both in organization and scope. It is organized as follows; first the study site is described followed by a literature review on the potential variables explaining forest cover change, by doing so the stage is set for the analysis of forest dynamics in Guatemala. In the second section the methods utilized for the analysis are described. In the third section the results of the analysis are presented followed by a discussion of the findings in the light of current literature on forest dynamics. In the final section a conclusion on the study is drawn.

Study site

The republic of Guatemala is situated in Central America, bordering Mexico to the north, Belize to the east and El Salvador and Honduras to the south (Figure 1).

Guatemala was under Spanish colonization between 1524 and 1821 (Lovell, 1985) and the recent history has been dominated by the civil war, lasting from 1960 until 1996 (Mauro and Merlet, 2003). Dynamics that have been identified as contributing to the outbreak of the civil war are the unequal distribution of land, exclusion of a large proportion of the population from their basic rights, and the oppression of the political opposition (Plant, 1995; World Bank, 2002b; Mauro and Merlet, 2003; Macours, 2009). The

peace negotiations began in the early 1990s, and the Peace Accords were signed in 1996. Through the Accords the government committed to initiate several reforms dealing with social inequalities (World Bank, 2002b).



Figure 1. Map showing the situation of Guatemala in the world (Tripatlas, 2010).

The country comprises an area of 106 445 km² (MAGA, 2002). Two thirds of the country is mountainous and volcanic, and the mountainous highlands run from the Mexican border across the country to the Honduran and Salvadoran border (Southgate and Basterrechea, 1992; World Bank, 2003a). The country is administratively divided in 22 departments and 330 municipalities (MAGA, 2002) (Figure 2).

The climate varies between the hot humid lowlands to the cooler highlands, with El Petén and the Caribbean lowlands being warm year round while frost can occur at higher elevations. The country experience two main seasons, the rainy season from May to October and the dry season from November to April, but the amount and timing are subject to great local variations (Melgar, 2003). Annual precipitation varies between 500 and 5600 mm. The wettest areas are the Pacific slopes and along the rim of the highlands on the northern side, and a belt of dry area stretches from the borders of Honduras to west of the capital city (MAGA, 2002).

The location between two continents with different biological life in combination with great variations in topography, soil, altitude, and climate gives Guatemala an exceptionally high diversity in plants and animals (Southgate and Basterrechea, 1992; Melgar, 2003). The natural vegetation type in Guatemala is

forest, and the great spatial variation in physical variables also results in a range of different forest types (Figure 3).



Figure 2. Map showing the 22 departments of Guatemala (Questconnect, 2010).

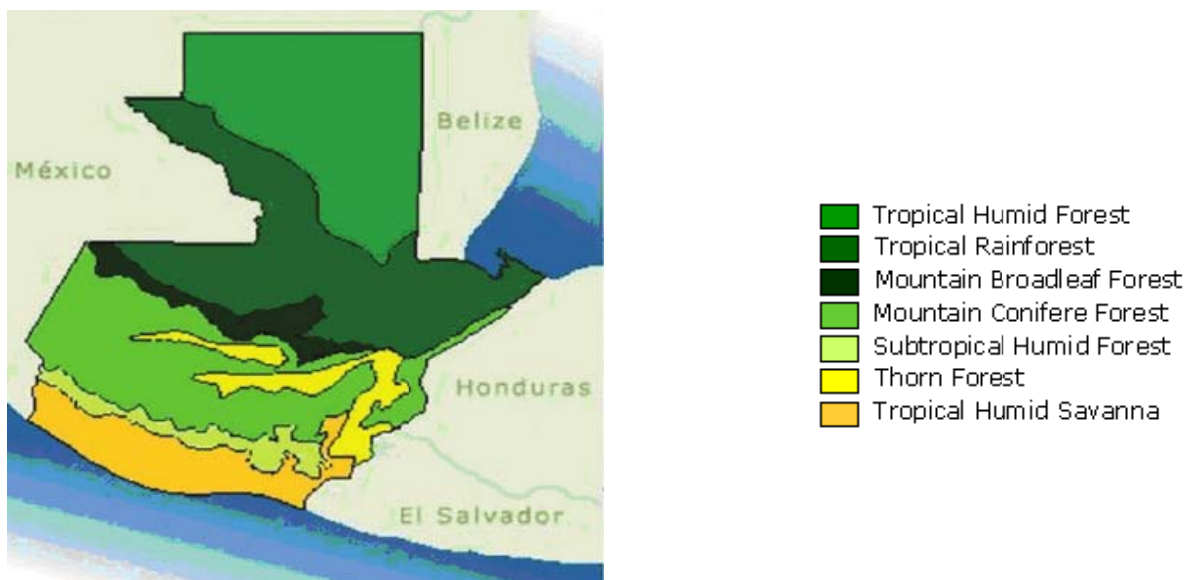


Figure 3. Map of forest types in Guatemala (CONAP, 2009b).

Guatemala had a forest cover of 47% in the beginning of the 1990s, and the forested area decreased to 42% in a ten-year period. During the time period of this study 563 176 ha forest were lost, and the annual deforestation rate was 1.43 % (UVG et al., 2006) (Figure 4).

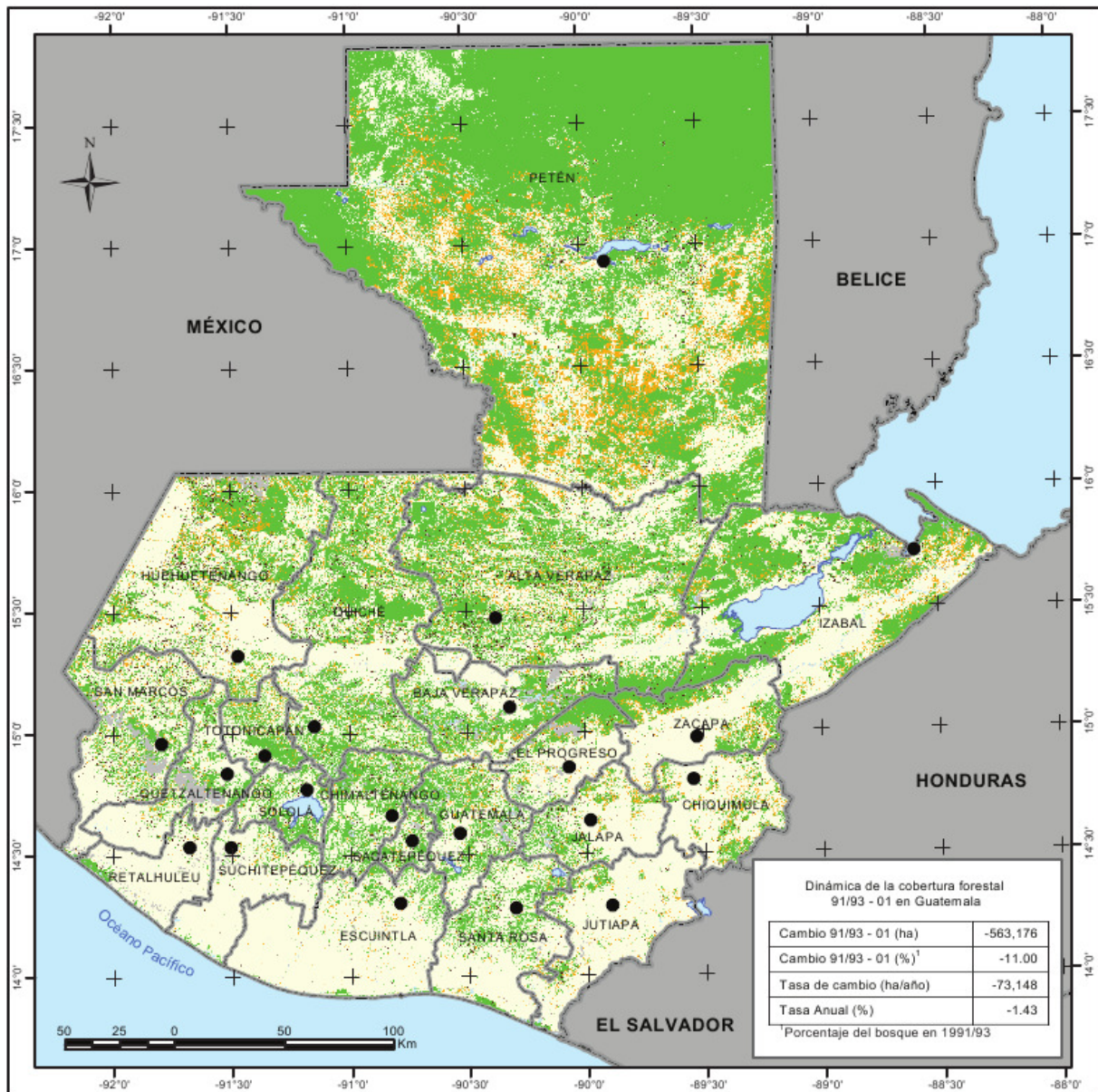


Figure 4. Map of Guatemala showing forested areas ■, areas with net forest loss ■, and areas with reforestation ■ in the period of the study (UVG et al., 2006).

Potential variables causing forest cover change in Guatemala

Population density and population growth

The total population living in the world at the turn of the millennium was just above 6 billion, with an annual growth rate of 1.3% (Population Reference Bureau, 2009). Population growth has been strongly associated with increased pressure on forest resources and deforestation by a range of studies (e. g. Myers, 1991; Vanclay, 1993; Koop and Tole, 2001; Ehrhardt-Martinez et al., 2002; Laurance, 2002; Siren, 2007). According to Melgar (2003), increasing population densities have resulted in increasing demand for land for human settlement and agricultural production with exacerbating deforestation rates as a result. The population in Guatemala increased from 2.8 million in 1950 to more than 11 million in 2001, an increase of more than 400% (Rivadeneira, 2001; INE, 2005). Between 1994 and 2002 population numbers continued to increase by 3.1% annually, and at the same time population density increased by 34%¹.

Urban population and urbanization

The world's population is becoming increasingly urbanized, caused mainly by rural-urban migration and the expansion of the boundaries of urban areas (UN, 2002). Brea (2003) explains the migration trends by a combination of two processes; governmental investments in industry in urban areas creating attractive employment alternatives, and agrarian reforms reducing labor demand in the agricultural sector. Mather and Needle (1999), Klooster (2003), and Jorgenson (2006), among others, documented the positive effect of urbanization of developing countries on forest cover.

Guatemala has also experienced a transition from a highly rural population towards more urbanized population pattern. However, the transition is markedly slower than the general trend in Latin America, and the country is still dominated by a high rural population depending directly on natural resources for their survival (Mauro and Merlet, 2003). However, in the eight-year period of this study, the urbanization rate was at exceptionally 82%², yet the spatial variation in urban population densities is great. Out of the urban population in 2002, 42 % of them lived in Guatemala City, and 60% of them lived in four of Guatemala's 22 departments; Guatemala, Escuintla, Chimaltenango, and Quetzaltenango (INE, 1996; INE, 2005).

¹ Population density was 78 per km² in 1994 and 106 per km² in 2002 (INE 1996; INE 2005).

² The urban population increased from 34% of the population in 1994 to 46% of the population in 2002 (INE, 1996; INE, 2005).

Extreme poverty

According to UN (2005) one billion people were extremely poor in the world in 2005, living on less than US\$1 a day. Poor households are found to be highly dependent on agriculture and natural resources (Pijanowski et al., 2010), and are associated with unsustainable utilization of forest resources (Lewis, 1996; Angelsen and Wunder, 2003; Chomitz, 2007). Researchers have linked poverty to land use and forest by either explaining continued poverty with high forest cover (Chomitz, 2007), or explaining deforestation with poverty (Deininger and Minten, 1999). However, the poverty-deforestation link has lately been contested by several researchers (e.g. Angelsen and Kaimowitz, 1999; Pijanowski et al., 2010), and some also reveal a negative impact of economic growth on deforestation (Lopez, 2005; Zwane, 2007).

Poverty levels in Guatemala are among the highest in the Latin America and the Caribbean region and have changed little since the late 1970s, despite positive economic growth during much of the time period (Vakis, 2003; World Bank, 2003a; World Bank, 2004). Poverty rates in Guatemala are found to be negatively biased towards rural populations, indigenous people, and areas with high conflict levels during the late civil war (Baumeister, 2003; World Bank, 2004; UNDP, 2005). In 2000, 26% of the population was below the national extreme poverty line in Guatemala (MAGA, 2000).

Use of firewood for cooking

In developing countries, a large proportion of the households depend on biomass fuels to cover for energetic needs, like light, heating and cooking. Wood resources are a common source of biofuel; in some areas, wood comprises more than 90% of the utilized biomass (DeMontalembert and Clement, 1983, Bhatt and Sachan, 2004; International Energy Agency (IEA), 2006). Throughout the 1990s the demand for firewood by poor rural households was proposed as a principal contributor to deforestation (Verolme and Moussa, 1999; Macht et al., 2007). However, policy programs relying on a clear link between wood consumption and deforestation have largely failed, and today the association is much more debated. In Guatemala, a family relying on firewood for their energetic needs will use 15 m³ of wood per year (INAB, 2006) and in 2002 57% of the population utilized firewood for cooking (INE, 2005).

Indigenous population

Indigenous populations worldwide have suffered from discrimination and suppression since colonization. The distress includes structural and social discrimination, exclusion from access to social

services, information and opportunities, and lack of empowerment (Del Popolo and Oyarce, 2005; Ellison-Loschmann and Pearche, 2006; Hall and Patrinos, 2006; Marrone, 2007). Indigenous peoples are among the least privileged citizens in any country. Yet, they inhabit forests and make a living of the forest resources all over the world (Kramer and Van Schaik, 1997), and are recognized for their key role in the forest dynamics in Central America (Cayuela et al., 2006; Nepstad et al., 2006; Stocks et al., 2007; Figueroa et al., 2009).

Guatemala was first populated 4000 years ago by the Mayas practicing subsistence shifting cultivation in the lowlands in the northern part of the country. As the population grew, people moved into the highlands and intensified agricultural production (Melgar, 2003). When the Spanish colonization began, the indigenous population was stripped from their lands and pushed further into the highlands (Katz, 2000).

The indigenous population constituted 41% of the population in 2002 and consists of 23 ethno-linguistic groups, of which 21 are Mayan (World Bank, 2003a; INE, 2005). The indigenous Maya population has been living as subsistence farmers from pre-colonial time until today and has its own cultural values and institutions. These traditions have not been recognized by the non-indigenous power elite (Plant, 1998); rather, the indigenous population has been excluded and oppressed from the colonial time until today (World Bank, 2004). Over time, land has been concentrated in the hands of few (Bilsborrow and DeLargy, 1990; Gould, 2006), and after the independence new laws contributed to secure land in the hands of large non-indigenous land owners. The traditional land rights and forms of land administration have not acquired formal recognition until recently, as part of the Peace Accord process to end the civil war (Baumeister, 2003; Mauro and Merlet, 2003).

Human Development Index (HDI) and HDI growth

Economical aspects are interlinked with all other components in society, and are strongly involved in utilization of natural resources including forest (Verolme and Moussa, 1999). Yet, increasing deforestation rates have been explained both by positive economic development (Shandra, 2007) and negative economic development (Burns et al., 1994; Mertens et al., 2000).

A study exploring the link between deforestation and the Human Development Index (HDI)³ in biodiversity hotspots throughout the world revealed a complex relationship. A combination of low HDI scores and low population growth resulted in high deforestation rates (Jha and Bawa, 2006). Moreover, when HDI scores were high, deforestation rates were low regardless of population growth. In Guatemala, HDI scores have increased gradually since 1975, mainly caused by an increase in the economic component, and less in the health and education component (UNDP, 2005). Recently, the dominating role of the economic component in the HDI score has diminished. In the period between 1994 and 2002 the percentage increase in the general HDI score was higher than for the percentage increase in the economic component of the index⁴, possibly indicating a shift in the road of development (UNDP, 2005).

Economically active population working in agriculture

The International Labour Office (ILO) (2008) has estimated that three quarters of the world's poor live in rural areas and most of them make a living from agriculture, directly or indirectly. Expansion of agriculture into forest has been held responsible for deforestation (Ferroukhi, 2003; Lambin et al., 2003; Angelsen, 2007; Rudel et al., 2009; Barbier et al., 2010) and previous work has found a positive link between populations working in agriculture and deforestation rates (Rudel and Roper, 1997; Ramankutty and Foley, 1999; Wright and Samaniego, 2008).

The proportion of the population participating in the agricultural sector in Guatemala is the highest in Central America (Solórzano and Del Cid, 2003). In 2002 agriculture, hunting, forestry, and fisheries employed 42% of the economically active population and 13% of the total population (INE, 2005). The agricultural sector has moreover played an important role in the history of Guatemala (Vakis, 2003), and still contributes significantly to the economy (World Bank, 2002b; World Bank, 2004). Development has generally been concentrated in areas with high agricultural potential, especially of agricultural export products (Alwang et al., 2005).

Densities of roads

Roads may have positive socio-economic effects by improving access to markets and employment in urban areas (Chomitz and Gray, 1996; FAO, 2000; Munroe et al., 2002; World Bank, 2004; Carr, 2005)

³ The HDI is an instrument for measuring development, including data reflecting health and education in addition to economical aspects (UNDP, 2005).

⁴ The increase was 10% for HDI and 7% for the economic component.

and negative effects like enhanced levels of conflict and undermining of local governance structure following increased levels of immigration (Perz et al., 2010). Expanding road networks have a direct negative effect on forests by fragmenting areas and disturbing ecosystem dynamics (Chomitz and Gray, 1996; Chomitz 2007; Coffin, 2007). The facilitated access to new areas generates enhanced immigration rates resulting in increased deforestation for agriculture and logging (Sader et al., 1994; Dourojeanni, 1999; Carr, 2005; Angelsen, 2007; Freitas, et al., 2010; Perz et al., 2010) In Guatemala such trends are especially evident in the northern parts of the country (Sader et al., 1994; Carr, 2005). Densities of roads in Guatemala in 2003 were 0.13 km per km² for paved roads and 0.67 km per km² when combining paved roads, unpaved roads and paths (IGN, 2003).

Slope

Numerous authors argue that remaining forests are mainly situated on steeper slopes (Deininger and Minten, 1996; Kaimowitz, 1996; Southworth and Tucker, 2001; Kaimowitz, 2008) and identify lower deforestation rates in steeper terrain (Ochoa-Gaona and González-Espinosa, 2000; Gibson et al., 2002; Freitas, 2010). Guatemala features great variations in topography, and the country is in some areas characterized by steep terrain. Land in steep terrain is often not suitable for agricultural production, and clearing may result in soil erosion (Bensel, 2008; Mohammad and Adam, 2010), constituting a major problem in Guatemala (Bilsborrow and DeLargy, 1990; Mauro and Merlet, 2003).

Initial forest cover

Some researchers have suggested existing forest cover as important for forest cover change dynamics (Rudel et al., 2005; Ewers, 2006; Angelsen, 2007; Wright and Samaniego, 2008; Crk et al., 2009), yet the proposed relationship between the two variables varies. While some researchers explain high deforestation rates with high occurrence of forest (Rudel et al., 2005; Angelsen, 2007), Barbier et al. (2010) explain deforestation with the perceived higher marginal benefit of alternative use of the forested land. On the other hand, Crk et al. (2009) find a positive effect of nearby forest cover on forest recovery, while Ewers (2006) relate positive forest cover change with a combination of low existing forest cover and high GDP. Rudel et al. (2005) argue that low forest cover may increase prices on forest products, and thereby motivate farmers to plant trees on less productive land. Guatemala had an initial forest cover of 47% at the period at the beginning of this study, which is considered as high compared to other countries, yet this is a considerable reduction from the forest cover some 40 years before that (Universidad Rafael Landívar et al., 2009).

Protected areas

Protected areas are emphasized to be among the most effective devices for the conservation of species (Lewis, 1996; Eken et al., 2004) and by some regarded as the single most important instrument (Rodrigues et al., 2004). According to Rodrigues et al. (2004) protected areas covered 11.5% of the world's land surface in 2004, and according to The National Council on Protected Areas (2000) protected areas covered 32% of the land surface of Guatemala.

The protected areas in Guatemala are governed under the Law for protected areas (Ley de Áreas Protegidas), passed in 1989. The National Council on Protected Areas was established and given a mandate as part of the implementation of the law (CONAP, 2003; Gomez, 2008). Tensions between the promoters of protected areas and the rural population are evident (Loening and Markussen, 2003), and insufficient resources for management leads to high susceptibility to illegal logging and expansion of the agricultural frontier within the boundaries of the protected areas (Universidad Rafael Landivar, 1987; Bonham et al., 2008).

Communal lands

According to a study by Richards (1997), common property land tenure is more likely to be successful in achieving environmental and equity goals than other tenure regimes if sufficient institutional and policy support is provided. Communal lands cover 12% of Guatemala (CONAP, 2009a). Common property is one of four land tenure regimes in Guatemala, the others being private property, state property, and municipal property. The communal lands belong to the communities and are administered by shared collective user rights (Ferroukhi, 2003). Gaining recognition from the government and policymakers is however a challenge (Richards, 1997; Tucker, 1999), also in Guatemala (Tucker et al., 2007). Still, Elías et al. (1997; 2009) suggest that the large tracts of forest found in the highlands can be attributed mainly to municipal and communal land tenure.

Methods

This study used a meta-analysis approach. Meta-analysis in this study is understood as a tool to systematically review a large body of published and unpublished literature aiming at exploring the issue of focus. This concept has been used by other researchers in deforestation studies to draw generalized conclusions of causes of deforestation (Geist and Lambin, 2001; Keys and McConnell, 2005; Rudel et al., 2009).

Studies reviewed and included in the analysis met the following criteria: They included data from Guatemala potentially explaining forest cover change; the data was available at municipality or lower levels, and originating from approximately the same time period as the data on forest cover change. Data from the selected studies were collected and transformed so that the analysis could be conducted. Statistical procedures and qualitative investigations were then used to investigate the relationships between the set of variables that could be relevant to explain deforestation in Guatemala (Bangert-Drowns and Rudner, 1991). The results were further explored by utilizing quantitative and qualitative information available in the literature, with a focus on literature from developing countries and Latin America.

Forest cover change in this study was analyzed during an eight-year period from 1993/94 until 2001. The selection of the period to be studied was constrained by data availability. The response variable was forest cover change. Forest cover change in this study was measured as (i) net forest loss; defined as hectares forest lost and gained throughout the time of the study, (ii) annual deforestation rate; defined as percentage forest cover change annually, and (iii) deforestation; defined as log transformed forest cover in 1993-94 divided by forest cover in 2001.

The data on forest cover are from a report prepared by Universidad del Valle de Guatemala (UVG), the National Forestry Institute, and the National Council for Protected Areas (2006) estimating forest cover change between 1991-93 and 2001 at the level of the municipality, department, and region. The report defined forest as an area of more than 0.5 hectares with a minimum canopy cover of 40% (UVG et al., 2006). The report was based on analysis of LANDSAT satellite images, maps, photographs, and ground verification. The satellite images were analyzed and grouped in forest areas and non-forest areas and then validated by aerial photographs and field data.⁵ The use of satellite images for investigating forest

⁵ For further explanation about the methods, see UVG et al. (2006).

cover change is common (e.g. Green and Sussman, 1990; Skole and Tucker, 1993; Sader et al., 1994; Chowdhury, 2006; Andam et al., 2008), often in combination with ground-based surveys (Turner et al., 1993; Southworth and Tucker, 2001; Cayuela et al., 2006).

Forest cover change was analyzed in relation to a number of demographical, economical, biophysical, and institutional variables. Data was gathered from several sources (Table 1) and used to perform qualitative analysis at region and department level and quantitative analysis at department and municipality level. Explanatory variables were included even if they did not originate in exactly the same time period as the forest data, as long as they were recognized as relevant in relation to forest dynamics during the actual period.

Table 1. The sixteen explanatory variables explored in this study and the sources of data.

	Variable	Source of data
Response variables	Net forest cover loss (ha) between 1993-94 and 2001	UVG et al. (2006)
	Deforestation (log (forest cover 1993-94/forest cover 2001))	UVG et al. (2006)
	Deforestation rate annually in percentage between 1993-94 and 2001	UVG et al. (2006)
Explanatory variables	Population density 2002	INE (2005)
	Population growth rate (population density 1994/population density 2002)	INE (1996) and INE (2005)
	Urban population in percentage 2002	INE (2005)
	Urbanization rate (urban population 1994/urban population 2002)	INE (1996) and INE (2005)
	Extreme poverty levels 2000	MAGA (2000)
	Firewood use for cooking in percentage 2002	INE (2005)
	Indigenous population in percentage 2002	INE (2005)
	HDI score in 2002	UNDP (2005)
	HDI change in percentage between 1994 and 2002	UNDP (2005)
	Economically active population working in agriculture in percentage in 2002	INE (2005)
	Paved roads density in 2003	IGN (2003)
	All types of roads density in 2003	IGN (2003)
	Slope index	MAGA (2002)
	Initial forest cover in 1993-94 percentage	UVG et al. (2006)
	Protected area coverage in percentage in 2000	MAGA (2000)
	Communal lands coverage in percentage in 2009	CONAP (2009)

In order to explore the drivers behind forest cover change across several geographical scales, the country was divided in regions above department level. There are several alternative ways to divide the country into regions. For this study, a slightly modified version of the regional division utilized by the National Forestry Institute in the report “Boletín de Estadística Forestal” 1999-2004 (INAB, 2006) was employed. The regions were named according to their geographic location (Table 2).

Table 2. The regional division of Guatemala above department level utilized in this thesis.

Regions	Departments
North	Alta Verapaz, Baja Verapaz
North-east	Izabal, Zacapa, Chiquimula, El Progreso
Central	Sacatepéquez, Chimaltenango
North-western highlands	Quiché, Huehuetenango
South	Suchitepéquez, Escuintla, Retalhuleu
South-east	Jalapa, Santa Rosa, Jutiapa
South-western highlands	Quetzaltenango, San Marcos, Totonicapán, Sololá
El Petén region	El Petén department
Guatemala region	Guatemala department

Potential variables driving forest cover change in Guatemala

Information on population number, urban population number, use of firewood for cooking, indigenous population, and population working in agriculture was gathered from two censuses prepared by the National Bureau of Statistics (Instituto Nacional de Estadística, INE) from 1994 and 2002 (INE, 1996; INE, 2005). The area of the administrative regions was obtained from a database prepared by the Ministry of Agriculture (Ministerio de Agricultura, Ganadería y Alimentación, MAGA, 2002).

Population density in 2002 was estimated by dividing population numbers by area, and population growth rate was estimated by dividing population density in 1994 by population density in 2002. The proportion urban population was estimated by dividing the number of people living in urban areas by the number of people residing in the area. The urbanization rate was estimated by dividing the urban population numbers in 1994 by the urban population numbers in 2002. In the data prepared by INE urban areas were considered as cities, towns, villages, or other populated sites with more than 2000 inhabitants among which 51% or more of the households had access to piped water and electricity for lighting (INE, 2005).

Data on extreme poverty was gathered by the Ministry of Agriculture in 2000 and presented in “Atlas Temático de la República de Guatemala” (MAGA, 2002). Extreme poverty in Guatemala is defined as people living in households with insufficient income to cover for their daily food requirements. This is estimated to 1500 Quetzales a family per month or about US\$1.50 per day. The use of firewood for

cooking was estimated from data on household's use of energy sources for cooking. INE (2005) listed five categories of energy sources; electricity, propane gas, kerosene, firewood, and coal. The percentage of households using firewood was used for this study.

The proportion of the indigenous population was defined as the percentage of the indigenous population in 2002. This report made use of data on human development index (HDI) scores from Guatemala obtained from a report by the United Nations Development Programme (UNDP, 2005). HDI includes measurements reflecting health and education in addition to the economical aspect; each of the components has the same weighing in the calculation of the index. The economic index is measured as the GDP (Gross Domestic Product) per capita in purchasing power parity (PPP) US\$, and includes a rate of exchange accounting for price differences across countries. The health aspect is measured through life expectancy at birth, and the education aspect is measured through educational attainment and adult literacy rate (UN, 2005). The change in HDI was estimated by dividing the scores in 1994 by the scores in 2002.

Estimates of the percentage of the population working in agriculture were made from data on the economic activities of the economically active population above 7 years from the 2002 census (INE, 2005). The census grouped the number of economically active people working in agriculture, hunting, forestry, and fisheries in one category, and this was used as a measure of the population working in agriculture. The data was utilized to estimate the percentage of the economically active population working in agricultural related activities, henceforth termed economically active population working in agriculture. Wright and Samaniego (2008) justified the use of this confined term based on the notion that most of the people included in this category will practice subsistence agriculture to some degree.

Data on roads was obtained from a database prepared by the National Geographic Bureau of Guatemala (Instituto Geográfico Nacional, IGN) in 2003. The data base presented extension of paved roads, unpaved roads, and paths in kilometers. For this study two road density indexes were estimated by dividing the distance of paved roads by area and distance of all roads (including paved roads, unpaved roads and paths) by area. Data on slope was obtained from "Atlas Temático de la República de Guatemala" (MAGA, 2002). The data categorized land into seven groups according to the slope in degrees. The groups were 0-3%, 3-7%, 7-12%, 12-25%, 25-50%, 50-75%, and more than 75%. An index was prepared from these categories by estimating the median in each group, multiplying the median

with the area in each group, summarizing the numbers for each municipality, and dividing the number by total area in each municipality.

Initial forest cover in 1991-93 was included as a variable in the analysis, with data from the report by UVG et al. (2006). The information about protected areas used in this study was gathered from data prepared by the Ministry of Agriculture (MAGA, 2000), and utilized to estimate percentage of the area covered by protected area. Data from a report by the National Council on Protected Areas (2009) was used to estimate the percentage covered by communal lands. Even if the report on communal lands was recent, the situation has apparently not changed significantly from the 1990s until today.

Qualitative analysis

In the qualitative analysis at region and department level, all three response variables and sixteen explanatory variables were used (Table 1). At region level, estimations of HDI score, HDI change, density of paved roads, density all types of roads, and slope index were found by adding together the estimations at department level. This extrapolation may have resulted in loss of some predictive quality. The other variables were calculated from the actual numbers or by adding together from municipality level. Data for the 22 departments was estimated by adding together the data from municipality level. Data on both levels was analyzed by intra-level comparisons of the variables in order to explore existing associations. Moreover, the data was compared across levels to explore cross-scale trends.

Statistical analysis

The data was statistically analyzed at department level and municipality level. Because of the low number of replicates at region level, statistical analysis was not carried out. Three of the explanatory variables were excluded from the statistical analysis because they measured the same factor as another variable, and thereby had high inter-correlation. The excluded variables were population density in 2002 (variation of population growth rate), percentage urban population in 2002 (variation of urbanization), and HDI score in 2002 (variation of HDI change). All other explanatory variables at department and municipality level were tested for correlation by estimating the Pearson's product-moment correlation coefficient (Appendix 1) (Appendix 2).

At department, level nine of the initially sixteen explanatory variables were excluded from the statistical analysis because of high inter-correlation among variables ($r > 0.5$); the variables excluded in this process

were: population density, percentage urban population, percentage of the population using firewood for cooking, percentage indigenous population, HDI score, percentage economically active population working in agriculture, density of all types of roads, and percentage of protected areas. At municipality level six of the initial sixteen explanatory variables were removed for the same reason. The excluded variables were population density, percentage urban population, percentage using firewood for cooking, indigenous population, HDI score, and percentage communal lands.

The statistical analysis at municipality level was performed in two out of the nine regions; the South-east region comprising the departments of Jalapa, Jutiapa and Santa Rosa, and the South-western highlands comprising the departments of Quetzaltenango, San Marcos, Totonicapán, and Sololá (Table 2). The South-east region includes 38 municipalities and covers an area of 8512 km². The South-western highlands includes 79 municipalities and covers an area of 7800 km² (MAGA, 2002). The focus on two of the regions enabled the inclusion of municipality level analysis within the scope of this thesis, and according to literature (e.g. Plant, 1995; Rivadeneira, 2001; Alwang et al., 2005), the two regions present initial obvious similarities and differences making them interesting to compare.

Multiple regression analysis was employed in this study, starting with the full model including the all potential explanatory variables that were not excluded because of correlation (Table 1). The program used for performing the multiple regression analysis was the software R, version 2.11.1 (R-project, 2010). The estimation of deforestation as $\log(\text{forest cover } 1993-94 / \text{forest cover } 2001)$ is based on a recommendation by Crawley (2007) for data where the response variable estimates rate of change. Region was entered as a dummy variable (coded 0, 1), and initial forest cover was entered as an explanatory variable in the model in order to account for in the effect of the standing forest. Model reduction was done by subsequently removing the least significant variable until only significant variables ($p < 0.05$) remained in the most parsimonious model.

Results

Region

The regions with the greatest net forest loss and the highest deforestation rates throughout the time of the study were El Petén region, North-east, and North-western highlands (Table 3). The regions with the lowest net forest loss and lower deforestation rates were Central, Guatemala region and South. The highest population density in 2002 was found in Guatemala region and Central, the same regions experiencing low population growth during the period of the study. The lowest population density was found in El Petén region, also experiencing the lowest population growth. The highest population growth was found in South-east and South-western highlands (Table 3).

The highest proportion urban population in 2002 was found in Guatemala region and Central, both also experiencing high urbanization rates. The lowest proportion urban population was found in North-western highlands and North region. The highest urbanization rates were found in El Petén region, and the lowest urbanization rates were found in South-western highlands and North-western highlands region. The results show large interregional differences in extreme poverty levels. The highest levels were found in both regions in the Western highlands. The lowest levels were found in Guatemala region and Central (Table 3).

Use of firewood for cooking was highest in the regions in the Western highlands and North, and lowest in Guatemala region. The highest percentage of indigenous people was found in the North and North-western highlands, the lowest was found in the regions of South-east and North-east. The regions with the highest score on HDI throughout the study were Guatemala region and Central; the lowest scores were found in North-western highlands and North region. The highest increase in HDI score in the period between 1994 and 2002 were in South-western highlands and South region, while Guatemala region and El Petén region experienced little improvement in HDI levels. The highest proportion of economically active population working in agriculture was found in the North, North-western highlands and El Petén region, the regions with the lowest proportion were Guatemala region and Central. Guatemala region and South had high densities of both paved roads and all types of roads. Central had high densities of paved roads while South-western highlands had high densities of all types of roads. Low densities of both types of roads were found in El Petén region, North, and South-east (Table 3).

The highest slope index was found in South-east region, while the lowest index scores were found in El Petén region and South region. The regions with the highest forest cover in the period at the start of the study were El Petén region and Central, the lowest forest cover was found in the South and South-east.

There were large interregional differences in the proportion of the protected areas. El Petén region had the highest area under protection, amounting to 25237 km² constituting 26 % of the protected land area in the country. Other regions with high proportion of protected areas were North-east and South-western highlands. Lower cover was found in South, South-east and North-western highlands. The highest proportion of communal lands was found in the regions of North-east and North, and the lowest in Guatemala region and South.

Department

The qualitative analysis at department level showed that the highest deforestation rates were experienced by El Petén department and Chiquimula (initial forest cover 73% and 24% respectively), and the lowest deforestation rates were found in Sacatepéquez, actually gaining forest cover, and Sololá with no observable forest loss, both having initial high forest cover (Sololá 43% and Sacatepéquez 45%) (Table 4).

The departments with the highest population density in 2002 were Guatemala department and Sacatepéquez. The departments with the lowest population density were El Petén department and Izabal. The highest population growth rate was found in Santa Rosa, Quetzaltenango, San Marcos, Jalapa, and Izabal, and the lowest was found in El Petén department and Quiché. The highest proportion urban population was found in Guatemala department and Sacatepéquez, the highest proportion rural population was found in Alta Verapaz and San Marcos. Urbanization rates were highest in El Petén department and Jalapa and lowest in Totonicapán and San Marcos.

Two departments in the western highlands showed especially high levels of extreme poverty, namely Totonicapán and San Marcos. Out of the five departments with the highest levels of extreme poverty, four of them were situated in the western highlands. The departments showing the lowest levels of extreme poverty were Sacatepéquez, Guatemala, and Escuintla. Quiché and Totonicapán had the highest percentage use of firewood for cooking, the lowest was found in Guatemala department and Sacatepéquez (Table 4).

Table 3. The scores of the response variables estimating forest cover change and the explanatory variables potentially driving forest cover change at region level.

Region	Response variables																Explanatory variables															
	NFCL	DF	DFR	PD	PG	UP	U	EP	FU	IP	HDI	HDIC	EAPA	PR	AR	SI	IFC	PA	CL													
North	-58698	-0.10	-0.83	73	0.70	22	0.75	34	86	85	0.54	11	69	0.03	0.55	10	47	8	19													
North-east	-76737	-0.14	-2.43	75	0.78	31	0.78	16	60	13	0.61	11	54	0.09	0.50	10	46	31	24													
Central	-1540	-0.01	-0.07	289	0.71	66	0.79	8	62	66	0.67	13	45	0.23	0.69	9	49	16	4													
North-western highlands	-59600	-0.11	-0.83	103	0.71	23	0.63	39	88	75	0.53	10	67	0.16	0.66	10	40	4	14													
South	-4650	-0.06	-0.63	138	0.74	43	0.76	12	59	26	0.61	15	47	0.21	0.74	3	9	3	2													
South-east	-11525	-0.07	-1.84	110	0.80	31	0.76	24	70	7	0.59	10	64	0.09	0.55	14	19	4	14													
South-western highlands	-10023	-0.04	-0.16	265	0.79	38	0.61	42	78	59	0.58	15	48	0.16	0.89	10	31	17	11													
El Petén region	-331034	-0.13	-2.65	10	0.61	30	0.89	20	80	31	0.62	7	67	0.02	0.15	3	73	70	14													
Guatemala region	-3173	-0.04	-0.33	1159	0.71	86	0.82	5	11	14	0.80	3	7	0.27	0.75	8	41	2	1													

Variables in the table: NFCL: net forest cover loss (ha) between 1993-94 and 2001; DF: deforestation (log (forest cover 1993-94/forest cover 2001)); DFR: deforestation rate annually in percentage between 1993-94 and 2001; PD: population density in 2002; PG: population density 1994/population density 2002; UP: urban population in percentage 2002; U: urbanization rate (urban population 1994/urban population 2002); EP: extreme poverty levels in 2000; FU: firewood use for cooking in percentage 2002; IP: indigenous population in percentage 2002; HDI: HDI score in 2002; HDIC: HDI change in percentage in between 1994 and 2002; EAPA: economically active population working in agriculture in percentage 2002; PR: paved roads density in 2003; AR: all types of roads density in 2003; SI: slope index; FC: initial forest cover between 1993 and 94 in percentage; PA protected area coverage in percentage in 2000; CL: communal lands coverage in percentage in 2009.

Table 4. The scores of the response variables estimating forest cover change and the explanatory variables potentially driving forest cover change at department level.

Department	Response variables																Explanatory variables															
	NFCL	DF	DFR	PD	PG	UP	U	EP	FU	IP	HDI	HDIC	EAPA	PR	AR	SI	IFC	PA	CL													
Sololá	-13	0.00	0.00	296	0.72	49	0.68	24	87	96	0.58	27	52	0.28	0.67	10	43	86	4													
Totonicapán	-5268	-0.11	-0.95	315	0.80	36	0.30	61	88	98	0.54	16	25	0.12	1.07	12	48	14	44													
Quetzaltenango	-816	-0.02	-0.19	293	0.81	55	0.72	29	61	54	0.66	14	39	0.15	0.98	8	23	7	12													
Suchitépéquez	-1490	-0.06	-0.55	171	0.76	41	0.74	15	71	52	0.59	16	53	0.21	0.79	4	10	5	0													
Retalhuelu	401	0.03	0.46	142	0.78	36	0.76	16	70	23	0.63	13	50	0.30	0.88	3	7	1	5													
San Marcos	-3926	-0.04	-0.46	224	0.81	22	0.60	59	84	31	0.54	6	67	0.10	0.83	9	28	5	3													
Huehuetenango	-30966	-0.14	-1.26	115	0.75	23	0.64	39	86	65	0.56	10	71	0.04	0.66	11	33	12	9													
Quiché	-28634	-0.09	-0.98	90	0.67	25	0.62	40	91	89	0.51	10	62	0.06	0.58	10	46	7	28													
Guatemala department	-3173	-0.04	-0.33	1159	0.71	86	0.82	5	11	14	0.80	3	7	0.27	0.75	8	41	2	1													
El Petén department	-331034	-0.13	-2.65	10	0.61	30	0.89	20	80	31	0.62	7	67	0.02	0.15	3	73	70	14													
Jutiapa	-7842	-0.25	-2.17	117	0.79	27	0.75	25	71	3	0.59	11	63	0.12	0.58	11	11	5	20													
Jalapa	-719	-0.01	-1.42	119	0.81	32	0.86	34	77	19	0.57	11	69	0.05	0.53	23	25	3	22													
Santa Rosa	-2691	-0.04	-0.34	95	0.82	35	0.69	17	70	3	0.60	8	61	0.10	0.54	7	24	4	2													
Alta Verapaz	-50290	-0.10	-1.22	72	0.70	21	0.75	36	87	93	0.51	12	69	0.03	0.58	9	47	8	15													
Baja Verapaz	-8408	-0.07	-0.64	75	0.72	27	0.75	31	82	59	0.58	10	67	0.04	0.52	11	44	9	35													
Escuintla	-3561	-0.09	-0.77	120	0.72	48	0.78	5	47	7	0.61	17	43	0.13	0.54	3	10	3	1													
Izabal	-41819	-0.12	-1.39	55	0.81	29	0.69	16	55	23	0.61	10	56	0.05	0.29	11	65	50	46													
Zacapa	-12188	-0.14	-1.34	74	0.78	39	0.73	13	56	1	0.64	11	49	0.09	0.56	9	34	26	2													
Chiquimula	-14388	-0.29	-2.46	126	0.76	26	0.97	16	71	17	0.56	13	59	0.09	0.60	9	24	1	11													
El Progreso	-8342	-0.15	-1.29	76	0.78	36	0.74	22	55	1	0.65	13	46	0.14	0.54	10	34	18	2													
Chimaltenango	-1612	-0.02	-0.16	239	0.71	79	0.53	12	73	79	0.62	16	54	0.17	0.72	9	50	12	4													
Sacatepéquez	72	0.00	0.03	462	0.73	84	0.84	4	42	42	0.71	10	31	0.30	0.66	9	45	34	6													

Variables in the table: NFCL: net forest cover loss (ha) between 1993-94 and 2001; DF: deforestation (log (forest cover 1993-94/forest cover 2001)); DFR: deforestation rate annually in percentage

between 1993-94 and 2001; PD: population density in 2002; PG: population growth rate (population density 1994/population density 2002); UP: urban population in percentage 2002; U: urbanization rate (urban population 1994/urban population 2002); EP: extreme poverty levels in 2000; FU: firewood use for cooking in percentage 2002; IP: indigenous population in percentage 2002; HDI: HDI score in 2002; HDIC: HDI change in percentage in between 1994 and 2002; EAPA: economically active population working in agriculture in percentage 2002; PR: paved roads density in 2003; AR: all types of roads density in 2003; SI: slope index; FC: initial forest cover between 1993 and 94 in percentage; PA protected area coverage in percentage in 2000; CL: communal lands coverage in percentage in 2009..

The departments with the highest proportion of indigenous people were Totonicapán and Sololá. The ones with the lowest proportion of indigenous people were El Progreso and Izabal. The general trend was a higher percentage of indigenous population in the western part of the country and Las Verapaces, and lower in the eastern and southern parts of the country.

The departments with the highest score in HDI in 2002 were Guatemala department and Sacatepéquez. The departments with the lowest score were Quiché and Alta Verapaz. All departments had positive change in HDI during the period. The departments with the highest percentage change in HDI score were Sololá and Escuintla, and the lowest change was experienced in Guatemala department and San Marcos. The three departments with the highest proportion of the economically active population working in agriculture were Huehuetenango, Jalapa and Alta Verapaz; the departments with the lowest proportion were Guatemala department and Totonicapán (Table 4).

Densities of paved roads were highest in Sololá and Guatemala department, and for all types of roads the densities were highest in Totonicapán and Quetzaltenango. El Petén department had the lowest densities of paved roads and all types of roads. The departments with the highest score on the slope index were Jalapa and Totonicapán, while Retalhuleu and El Petén department had the lowest score.

El Petén department and Izabal had the highest percentage forest cover at the beginning of the study period, while Retalhuleu department, Escuintla, and Suchitepéquez had the lowest forest cover. Departments with large proportions of its area under protection were Sololá and El Petén department. The departments with the lowest percentage cover of protected areas were Retalhuleu and Chiquimula. The departments with the highest percentage of communal lands were Izabal, Totonicapán, and Baja Verapaz. The departments with the lowest coverage of communal lands were Suchitepéquez, Guatemala department, and Escuintla (Table 4).

Statistical analysis revealed that deforestation rates were significantly higher in departments with low densities of paved roads (p-value: 0.01) (Table 5) (Figure 5).

Table 5. Deforestation rates at department level were significantly higher in departments with low density of paved roads.

Variable	Estimate	S.E.	t-value	p-value
Densities of paved roads	-0.45224	0.16806	-2.691	0.0141

Non significant variables removed through stepwise regression from the maximum model were: population growth rate; extreme poverty levels; initial forest cover in 1993-94; HDI change; slope index; percentage cover communal lands; region. R^2 : 0.27.

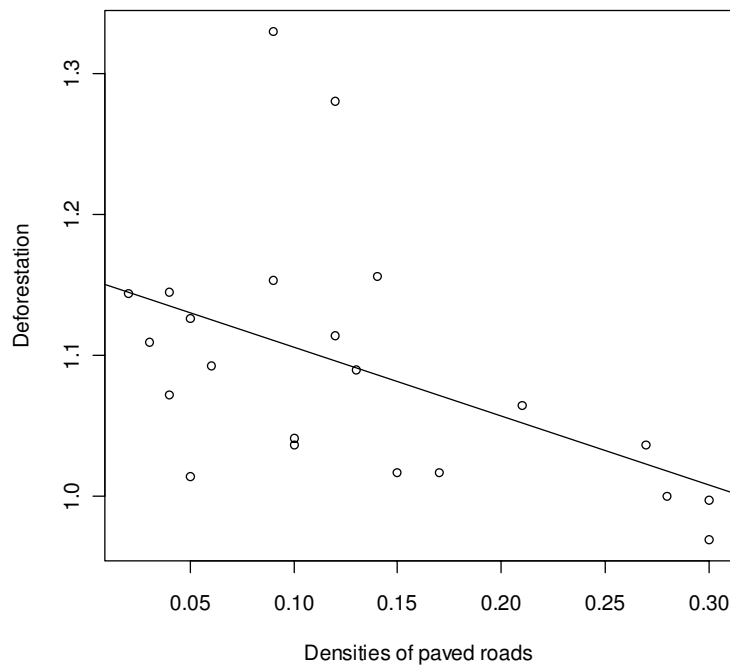


Figure 5. Deforestation rates at department level were significantly higher in departments with low density of paved roads.

Municipality

The statistical analysis revealed region as the strongest predictor of deforestation at municipality level (p -value < 0.001) (Table 6) with higher deforestation in the municipalities in the South-east region compared to the municipalities in the South-western highlands region. Moreover, the analysis showed that municipalities with high extreme poverty rates experienced higher deforestation (p -value: 0.0245) (Figure 6) and municipalities with low initial forest cover experienced significantly higher deforestation than municipalities with high forest cover (p -value < 0.0227) (Table 6) (Figure 7).

Table 6. Deforestation rates at municipality level were significantly higher in municipalities in the South-east region and in municipalities with high extreme poverty levels and low initial forest cover.

Variable	Estimate	S.E.	t-value	p-value
Region variable	-2.322e-01	3.324e-02	-6.984	<0.001
Extreme poverty levels	1.479e-03	6.487e-04	2.28	0.0245
Initial forest cover	-9.008e-06	3.899e-06	-2.310	0.0227

Non significant variables removed through stepwise regression from the maximum model were: population growth rate; urbanization; HDI change; economically active population working in agriculture; densities of paved roads; densities of all types of roads; slope index; communal lands. R^2 : 0.30.

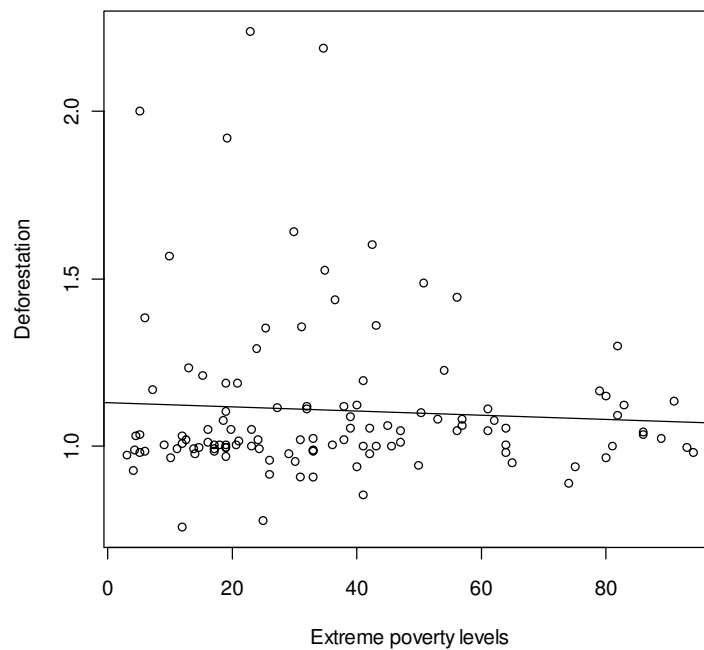


Figure 6. Deforestation rates at municipality level were significantly higher in municipalities with high extreme poverty levels.

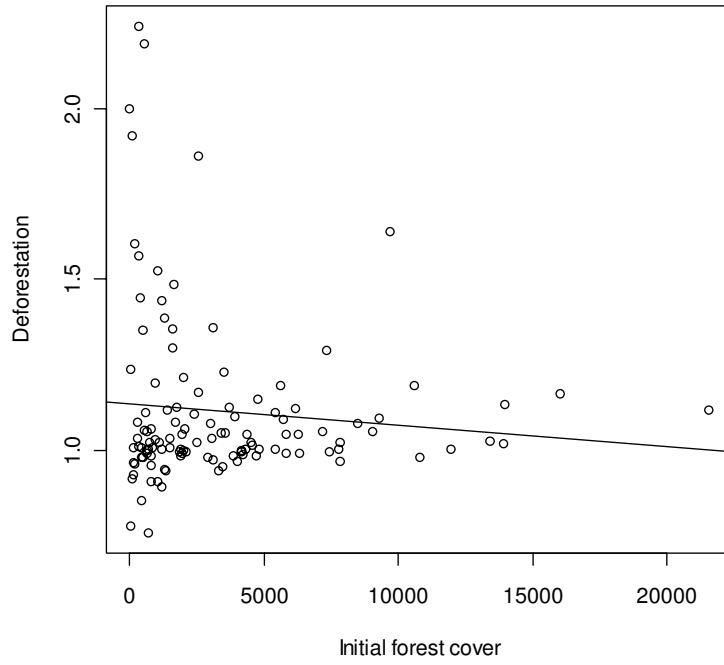


Figure 7. Deforestation rates at municipality level were significantly higher in municipalities with low initial forest cover.

Discussion

In order to halt deforestation rates and manage existing forest areas efficiently, the causes behind forest cover change must be identified and the dynamics understood (Honey-Rosés, 2009; Rudel et al., 2009). This study aimed to contribute to the field with an exploration of potential causes behind forest cover change in Guatemala. Several authors have emphasized the complex and context dependent dynamics causing deforestation both in Guatemala (Loening and Markussen, 2003; Carr et al., 2005; Tucker et al., 2005; Universidad Rafael Landívar, 2009) and in other developing countries (Deacon, 1994; Kaimowitz, 1997; Kaimowitz and Angelsen, 1998; Contreras-Hermosilla, 2000; Ewers, 2006). The results of this study support the previous findings; the observed forest cover change in Guatemala is likely to be a result of complex and context dependent dynamics including a combination of environmental, socio-economic and political factors. Nevertheless, the analysis of the data revealed significant associations, and specific trends acting on the different scales were observed.

Several authors emphasize the importance of geographical scale when studying forest cover change, and criticize studies only including data on national level (Klooster, 2003; Lesschen et al., 2005; Redo et al., 2009; Barbier et al., 2010). Nevertheless, cross-national studies only studying dynamics at country level are common in the forest cover change literature (e.g. Deacon, 1994; Rudel and Roper, 1997; Ehrhardt-Martinez, et al., 2002; Jorgenson, 2006). Honey-Rosés (2009) argues that by including several geographical scales in the analysis a more comprehensive exploration of the dynamics is possible. In this study three different scales were analyzed and compared, and the low degree of cross-level resemblance confirms the observations by several researchers that explanations may change when scale changes (Keys and McConnell, 2005; Redo et al., 2009; Barbier et al., 2010) which gives further support to the argument of Honey-Rosés (2009).

Guatemala experienced a 1.43% annual deforestation rate during the time of the study. This is 3.8 times higher than Brazil and 1.9 times higher than Mexico in the same period, countries well known for high deforestation rates. The difference can be explained by the smaller size of Guatemala, giving higher percentage change for same area deforested (UVG et al., 2006). FAO (2000) estimated that the world experienced 0.2% annual deforestation in forest cover in the 1990s, the figure was 1.2% for Central America, and 1.7% for Guatemala. Although the estimations differ, Guatemala is comparatively experiencing high forest cover change. In a similar time period as Guatemala experienced a reduction of

forest cover by 11%, population density increased by 34%, urban population increased by 82%, and HDI score increased by 10%.

Region

Region came out as the strongest variable explaining forest cover change at municipality level. When all of the nine regions of the country were compared, it became evident that Guatemala is a country characterized by great variation, making comparisons challenging. Some parts exhibit such extreme values that they are able to dominate the associations for the whole country. In many instances, El Petén region is regarded as extraordinary, with dynamics diverging from the dynamics found in the rest of the country. Both the large areas covered by forest, the low population densities, the isolated location, and the high recent immigration rates make El Petén region special (Plant, 1995; Shriar, 2002; Mauro and Merlet, 2003). This region scored the highest on all three variables measuring forest cover change; net hectare loss throughout the study period, deforestation, and annual deforestation rates, and in addition initial forest cover in 1993-94. Almost 60% of the deforestation occurring in the time of the study took place in El Petén region. However, also the two regions with the second and third highest net forest cover loss, North-east and North-western highlands, have little in common when compared across the other variables.

Guatemala City and its surroundings, included in Guatemala region, is another example of a region with extraordinary scores. The region holds 23% of Guatemala's population, and also differs from the national average in many of the other variables. Because more than a fifth of the population lives in this region, it has a noticeable impact on the national results including population numbers. For example, by excluding Guatemala region from the national data on use of firewood, the percentage increases from 57% to 73%, for economically active population working in agriculture the percentage increase from 42% to 56%, for percentage indigenous population from 42% to 49%, and for urban population the percentage decreases from 46% to 35%.

This study found that the regions with the lowest net forest loss and deforestation rates; Central, South-western highlands, South and Guatemala region, scored similarly on several of the included variables. Of the sixteen variables included, all of these regions provided high scores on proportion urban population, high densities of paved roads and all roads, low scores on economically active population working in agriculture, and low coverage of communal lands. This may suggest that these variables have importance for forest cover change. Interestingly, three out of four of these variables can be related to

development. The urbanization of the population (UN, 2004), the extension of road networks (Munroe et al., 2002), and the transition from agricultural work to the non-agricultural sector (World Bank, 2004) are all dynamics characterizing developing nations.

The link between development and low deforestation rates may imply that forest transition is occurring in Guatemala. According to the forest transition theory, a country experiencing economic growth will endure forest cover decline down to a certain level. When development continues beyond this point, deforestation will halt, and the standing forest cover will begin to increase. The forest transition will thereby follow a u-shaped curve (Mather and Needle, 1997; Mather et al., 1998; Perz, 2007). Many developed countries have throughout the 20th century demonstrated this relationship, and research has revealed the same trends in developing countries (Mather and Needle, 2000; Klooster, 2003; Barbier et al., 2010).

Department

The qualitative analysis revealed some tendencies of variables explaining forest cover change across departments, like the proportion urban population and densities of paved roads. The quantitative analysis revealed densities of paved roads as significantly explaining deforestation at department level. In addition, two of the most distinctive regions, El Petén region and Guatemala region are entirely made up of the respective departments carrying the same name, and generally the large differences occurring at region level also occur at department level.

Municipality

The strongest predictor of deforestation at municipality level was region, demonstrating higher deforestation in South-east region compared to South-west highlands region. The finding supports the argument of site specific dynamics demonstrated in the literature (e.g. Mather, 1992; Bonham et al., 2008; Tucker et al., 2008). The importance of site may also explain some of the deficiency in intra-level and inter-level similarities in associations.

The fact that there are clear regional differences reflects Guatemala as a country of contrasts. Most of the included variables exhibit large spatial variation, and together they produce complex local combinations challenging observations of general trends. The spatial variation also has implications for the management of forest and efforts to reduce forest cover change; site specific dynamics also requires site specific management regimes (Bonham et al., 2008).

The second strongest predictor of deforestation was initial forest cover. Lower forest cover was associated with high deforestation. The last variable found to be relevant was extreme poverty levels, with higher levels of extreme poverty found in municipalities with high deforestation rates.

By excluding one of each pair of the most correlated explanatory variables in the study, the strongest associative relationships not accounted for were avoided. However, the situation is complex; several sources from the literature demonstrate links between the explanatory variables used in this study.⁶ Thus, the correlative associations between the explanatory variables are a fact and the effect of these relationships could or should not be avoided completely.

An example of correlation between explanatory variables in Guatemala with a potential effect on deforestation is the link between poverty and geographic isolation caused by complex topography and lack of transport networks (Vakis, 2003; World Bank, 2004). Municipalities with low densities of paved roads and high slope index coincided with high levels of extreme poverty (Appendix 2), yet this was not evident at department and region level. The association implies that poor households live in steep areas with limited transport networks. Thus, even if only extreme poverty is found to be significantly impacting deforestation, slope and road densities may actually impact the association indirectly. Because of the complexity in the relationships between variables, they will be discussed in more detail in the following section.

Potential explanatory variables causing forest cover change

Population density and population growth

Neither population density nor population growth was found to correlate with forest cover change at any level. This contradicts conclusions drawn by other studies (Vanclay, 1993; Mather et al., 1998; Loening and Markussen, 2003) that suggest population growth to be an underlying factor behind deforestation, acting through the proximate factors of increased demand for arable land and forest products. The association between population growth and deforestation was also found by Myers (1991), yet he identified increased occurrence of shifting cultivation as the proximate factor.

⁶ See for example Mauro and Merlet (2003) for a link between ethnicity and poverty, Arriagada (2000) on a link between poverty and urbanization, and Tucker et al. (2005) on dynamics between slope, roads and distance to markets.

The link between population growth and deforestation has also been proposed for Guatemala. Loening and Markussen (2003) and a report by URL (2006) found population growth to be one of several causes behind the observed deforestation. The absence of any association between population growth and forest cover change in the data may be explained by the short time period for this study, thereby supporting the findings of Deacon (1994) of a time lag in response between population growth and deforestation.

Urban population and urbanization

At region level a link between the proportion urban population and forest cover change could be observed. The regions of Central, Guatemala region, South-western highlands, and South all have high urban populations and low score on net forest loss and deforestation rates. This trend is also evident when analyzing the data at department level quantitatively. This may suggest a positive effect of high urban population levels on forest cover conservation. The relationship with initial forest cover, which may have implied long term effects, is however not distinct. The quantitative analysis at municipality and department level revealed no correlation between urbanization and population working in agriculture (Appendix 1) (Appendix 2); however, the qualitative analysis at department level shows a tendency towards a negative association.

The urbanization of developing countries is generally found to have a positive effect on forest cover (Mather and Needle, 1999). Some authors suggest that urbanization may involve changes to a different set of perceptions of nature and forest, with more weight on the aesthetic and recreational values (Mather, 1992; Mather and Needle, 2000). This can lead to pressure for more protected forest areas and areas for recreational activities (Barbier et al., 2008). The results from this study do not support the link between protected areas and urban populations; however this association is probably acting on the national scale, and may have been detected in cross-national comparisons.

Jorgenson (2006) found that urban population growth reduced deforestation rates, while increase in the rural population had the opposite effect. Moreover, Ehrhardt-Martinez et al. (2002) found the highly particular association that urbanization led to increased deforestation rates until a threshold of 36% of the population lived in rural areas, whereby increases above this resulted in decreased deforestation rates. Klooster (2003) on the other hand, argues that urban areas offer more off-farm job opportunities, making agricultural work less attractive and thereby contributing to abandonment of agricultural land and leading to reforestation.

According to the data, the urban population in Guatemala has increased by 82% in an eight-year period, an exceptionally high increase for a country like Guatemala. This may indicate low quality of the data sources, namely the two population censuses prepared by the National Bureau of Statistics.

Extreme poverty

Extreme poverty levels were the third strongest variable at municipality level, higher levels of extreme poverty leading to higher deforestation. At department and region level, no clear link could be found. The association between high poverty rates and high deforestation rates found at municipality level has been identified by several researchers, often in combination with other factors (e.g. Vanclay 1993; Geist and Lambin, 2002; Wright and Samaniego, 2008), also in Guatemala (Segeplan, 2006; URL, 2006). Several researchers emphasize that poorer households are heavily dependent on natural resources for their day to day survival, and thereby constitute great stress on their environment (Pijanowski et al., 2010) and utilize unsustainable levels of forest resources (Lewis, 1996). Some researchers also link poverty to land use and forest by either explaining continued poverty with high forest cover, low population levels, and isolation (Chomitz, 2006), or explaining deforestation with poverty (Deininger and Minten, 1999).

To explain the link between poverty and deforestation Angelsen and Wunder (2003) and Chomitz (2006) emphasize the attractiveness of poorly paid forest activities to impoverished households with few other alternatives. Despite the low income possibilities, low input demand makes forestry an attractive option for households with low investment capacity.

One or several of the associations mentioned above may be relevant for Guatemala. Extreme poverty at municipality level was found to be strongly positively correlated with the use of firewood and slope, and strongly negatively correlated with density of paved roads, all of them often associated with the geographical isolation of rural areas (Appendix 2).

However, also regarding the association between poverty and forest cover change there are controversies. Angelsen and Kaimowitz (1999) are skeptical about the emphasized association between poverty and deforestation. They argue that there may be other factors in play not included when examining causes behind deforestation. Lower deforestation rates when income rises may instead be caused by improved access to off-farm work, and the alternative income activity is what actually discourages deforestation. Zwane (2007) finds a negative impact of economic growth on forest cover,

and Lopez (2005) provides evidence of the same and explains the link with expanding agricultural production following from the economic growth.

Use of firewood for cooking

The general trend revealed by the data was that a large proportion of the households in the western highlands and the northern parts of the country used firewood for cooking, while the Central and South region had lower percentages, and Guatemala region had levels way below any of the other regions. The regions with high use of firewood seem to be related to low percentage urban population. This supports the findings by Heltberg (2003), who proposes that the utilization of alternative energy sources for cooking is more common in the wealthier parts of the population, and that electrification and education is associated with switching away from firewood as a source of fuel. When considering that the definition of urban areas utilized by the National Bureau of Statistics includes a requirement for access to electricity for at least 51% of the population, the negative correlation between use of firewood for cooking and urban areas is as expected.

Use of firewood for cooking was not found to be important for forest cover change at any level; in that way the results from this study are inconsistent with the allegation made in a report by the World Bank (2002a) that firewood collection in Guatemala leads to deforestation. The findings are more in line with several researchers contesting the statement (Wunder, 1996; Rosero-Bixby and Palloni, 1998), finding little evidence of firewood leading to deforestation.

Indigenous population

Indigenous population levels were not found to be associated with forest cover change at any level. The general trend was a higher percentage of indigenous people in the western and northern part of the country, and lower in the eastern and southern parts of the country.

The data on indigenous population may, however, have suffered from underestimation, since the National Bureau of Statistics relied on self identification when gathering the information, and some indigenous people may choose to identify themselves as non-indigenous to avoid discrimination, an extensive problem in Guatemala (Plant, 1998; World Bank, 2003a). Data from the 2001 census estimated

that the indigenous population constituted 41% of the population, markedly lower than what has been reported by others⁷.

In Guatemala the link between ethnicity and poverty has been thoroughly documented, the indigenous population being marginalized and excluded from society and holding higher poverty rates (Plant, 1998; Brea, 2003; Mauro and Merlet, 2003; World Bank, 2003a; UNDP, 2005; Hall and Patrinos, 2006). The correlation test at department level showed that there is a correlation between high levels of extreme poverty and high percentage indigenous population in the subset (Appendix 1), and the same is indicated at the region level.

According to Cayuela et al. (2006), indigenous people play an important role in the forest dynamics in Central America. The National Council for Protected Areas (2003) found a concentration of forested areas in regions with high concentration of Maya population, mainly on communal lands. However, other studies find the association between forest cover and indigenous people to be complex, working on different temporal (Perz, 2007; Figueroa et al., 2009) and geographical (Nepstad et al., 2006) scales, and depending on the context (Redford and Stearman, 1993; Kramer and Van Schaik, 1997). The complexity of the issue may have obscured the observation of any existing relationship in the data.

Human development index (HDI) and HDI growth

This research revealed that HDI was not linked with forest cover change at any level. At country level, HDI levels have increased gradually since 1975, mainly caused by an increase in the economic factor, and less in the two others (UNDP, 2005). However, even when an increase in the economic component of the index is observed, the distribution of wealth among the population remains highly skewed; as illustrated by the low investments in social services and education, (UNDP, 2005).

In some areas the increase in HDI score is probably strongly influenced by the flow of remittances entering the country from migrant family members. Remittances constitute a substantial proportion of the country's GDP; 20% of the population received remittances in 2000 and in some households the money contributed up to 40% of the total income (Vakis, 2003).

In the literature, positive economic development has been linked to reduced deforestation rates (Shandra, 2007) and negative economic development has been coupled with increased deforestation

⁷ E.g. Meentzen (2001) reports the indigenous population to be as high as 66%.

rates (Burns et al., 1994; Mertens et al., 2000). Further, a study of the link between biodiversity hotspots and HDI scores throughout the world revealed high deforestation rates when HDI score was low and low deforestation rates when HDI score was high (Jha and Bawa, 2006).

Economically active population working in agriculture

The proportion of the economically active population working in agriculture was not found to be associated at any level with forest cover change. The data identify almost half of the economically active population as working in agriculture; however, several studies highlight the diversified livelihood strategies common in rural households, including a combination of agricultural production and other income generating activities (Plant, 1995; Baumeister, 2003; Vakis, 2003; World Bank 2004; Plant, 2005; International Labour Office, 2008). According to Plant (1998) the inclination to box people may give a wrong impression by it including people with any participation in agricultural activities as working in agriculture. Thereby, a notable proportion of the people included in this category may have several income alternatives making them less dependent on agricultural production and similar to people working in other economic sectors. This may have weakened any existing effect of the variable on forest cover change.

Loening and Markussen (2003) found a link between alternative employment opportunities in the non-farm sector in rural areas and deforestation in Guatemala, access to such alternative livelihood options leading to lower deforestation rates. The demand for alternative employment in rural areas is high, and if the association mentioned by Loening and Markussen is correct, an increase in non-agricultural work may have a reducing effect on deforestation rates. However, the data do not provide support for this association.

Densities of roads

The quantitative analysis at department level identified densities of paved roads as the single significant explanatory variable explaining 27% of the variation in deforestation at department level. The unexpected association found was higher deforestation in areas with low densities of paved roads. The qualitative analysis at department and region level confirmed this tendency; however, this association was not confirmed at municipality level.

The extension of road networks in Guatemala is based on a historical prioritization of areas of economical importance, like the coffee producing regions in the western highlands and areas with

export agriculture on the Pacific coast. Areas of low importance for agricultural export production have suffered from underinvestment in infrastructure, resulting in a high degree of isolation, especially during the rainy season (World Bank, 2003a; World Bank, 2004). Road development has been closely linked to general economic development in Guatemala (Alwang et al., 2005), yet no association was observed between density of paved roads, all types of roads, and HDI.

The literature provides support for the positive link between roads and development, and also a negative link with deforestation (Sader et al., 1994; Dourojeanni, 1999; Carr, 2005; Freitas, 2010; Perz et al., 2010) especially in areas with poor soils and low population densities (Chomitz and Gray, 1996). Freitas (2010) recognized long term effects of road development on deforestation rates and Southworth and Tucker (2001) identified lower deforestation in areas characterized by low road densities, steep terrain and at higher elevations. Thereby the results of this study are contradictory to what is found in the literature. The positive association between low densities of paved roads and deforestation at department and region level is caused by the areas with high forest cover, low road densities and high deforestation rates in the northern part of the country⁸. The absence of observed effect at municipality level may be a result of fewer areas with similar extreme associations in the South-east region and South-western highlands region.

Slope

Slope was not found to be associated with forest cover change at any level, contradictory to the negative association between deforestation and slope found previously (Ochoa-Gaona and González-Espinosa, 2000; Gibson et al., 2002; Freitas, 2010).

Interestingly there is little variation in the slope index between the different areas. It may be that the index was unable to capture the existing variation. At municipality level, high proportion indigenous population and low HDI levels characterized areas with steep terrain (Appendix 2). This may imply that the effect of the historical pressuring of indigenous populations into steeper areas is still evident today.

⁸ Regions with low densities of paved roads and deforestation were El Petén region, North, and North east; departments low densities of paved roads were: El Petén department, Izabal, Zacapa, Chiquimula, Huehuetenango, and Quiche.

Initial forest cover

The second strongest predictor of deforestation at municipality level was initial forest cover in 1993-94. Municipalities with lower initial forest cover experienced higher deforestation. This trend is not obvious at department or region level. The association between existing forest cover and forest cover change has been observed by some researchers in the literature (Rudel et al., 2005; Ewers, 2006; Angelsen, 2007; Wright and Samaniego, 2008; Crk et al., 2009), however, most commonly it is not included as a variable at all. The significant effect of initial forest cover at municipality level implies that the factor may be more important than considered by the scientific community working with forest cover change. However, the negative association found in this study is opposite of what has been promoted in the existing literature. The results imply that in areas with low forest cover the forest further diminished, while areas with high forest cover experienced smaller changes. According to other empirical studies and the theory of forest transition, higher deforestation should occur in areas with high forest cover (Mather, 1992; Angelsen, 2007; Barbier et al., 2010).

At higher scale, some of the departments and regions with the highest initial forest cover experienced the highest deforestation rates. A remarkable detail regarding initial forest cover was the above average coverage in the two departments with highest percentage urban population and highest population density, Guatemala and Sacatepéquez. This finding gives further support to the positive relationship between forest cover and urban population mentioned earlier.

Protected areas

Protected areas were not found to contribute to lower deforestation rates in this study at any level. The absence of effect of protected area coverage on forest cover change may be a result of low efficiency in the management of the protected areas once they have been designated (Universidad Rafael Landívar, 1987; Bonham et al., 2008).

The idea that establishing a protected area is enough to conserve the values therein is obsolete, replaced by the acknowledgement of the importance of effective management with sufficient funding and efficient institutions (Carey, 2000; Dharmaratne et al., 2000; Ervin, 2003b). In Guatemala, the National Council for Protected Areas (2003) argues that protected areas are not prioritized by the government when governmental programs and budgets are developed, and resources to manage the areas are in deficit. Mauro and Merlet (2003) find that low compliance with rules and regulations is a challenge in more isolated areas, like El Petén and the western highlands. Evidence from El Petén

illustrates high deforestation rates inside protected areas (Carr, 2008), though the deforestation occurring outside the protected areas have been even higher (Loening and Markussen, 2003). Thus, as Bonham et al. (2008) argue, conservation in Guatemala has low prospects of succeeding without the support and participation of local populations. This is in line with international conservation models for protected areas that have moved away from a management strategy based on a complete separation of humans and nature towards a conservation regime including local stakeholders and resource users (Lewis, 1996; Nepstad et al., 2006; Garcia-Frapolli et al., 2009; Nagendra et al., 2009; Heinen, 2010).

Communal lands

Several authors highlight the importance of communal lands in conserving forest in Guatemala (Elías, et al., 1997; CONAP, 2003; Elías et al., 2009). The percentage covered by communal lands was not found to follow any clear trend, except a belt of low coverage stretching from the interior of the country towards the south. In the coastal areas the communal lands are large in number, however small in area. In the northern part of the country, the number of areas was smaller, but larger in area. Communal lands coverage was not found to be associated with changing forest cover at any level.

The lack of observed effect of communal lands is in line with the findings by Gibson et al. (2002) that the management system is more important than property rights regimes in conservation of forest in Guatemala. The literature also emphasizes the importance of the socio-economic, political and ecological context for the common property regime to function properly (Redford and Stearman, 1993; Ostrom et al., 1999; Tucker, 1999). Like Latin America in general (Richards, 1997), common property management in Guatemala is suffering from the absence of support by governments and policy makers (Tucker et al., 2007). Often the communities do not have titles to their land and the land tenure regime is complex with many regimes co-existing in some regions. Establishment of rights to traditional and communal lands was part of the Peace accords, yet so far the rights to the forest on communal lands have only been established for a limited group of communities (World Bank, 1995; Katz, 2000; Elías et al., 2009). All these obstacles may limit the effect of communal lands in preserving forest.

Other variables with potential effect

The selection of variables included in this study depended on available data on potential variables explaining forest cover change in Guatemala, a limiting factor being the availability of data at municipality level. Respectively, one shortcoming following from this may be the absence of variables

critical for forest cover dynamics. This may influence the outcome of the analysis, either by indirectly controlling some of the other variables included, thereby giving a wrong impression of the cause-effect relationship, or by dominating the dynamics and thereby obscuring any associations with other variables (Deacon, 1994).

Distribution of land and land titles is one factor that may have an impact on forest cover change, yet no data was found to explore this for the relevant period. The distribution of land in Guatemala is skewed, a small proportion of the non-indigenous population own large areas, while most of the indigenous farmers own less than necessary for the survival of a family. Attempts on land reform after 1954 have had little success (Plant, 1995; Plant, 1998; Mauro and Merlet, 2003), and currently the issue of land distribution is left to the market (World Bank, 2004). Small land holders and communal land holders rarely possess titles to their land, and since secure land titles often is a prerequisite for accessing credit, this leaves them with few options to invest in their land and achieve economic development (Vakis, 2003; Macours, 2009). Lack of land titles have been linked to deforestation (Jaramillo and Kelly, 1997; Fearnside, 2008). Farmers with insecure land titles or shortage of land may see agricultural expansion into forested areas as a viable livelihood option (MAGA, 1999; Angelsen and Wunder, 2003) especially since colonization programs launched in the 1960s and 1970s in Guatemala encouraged forest clearing as an indicator of *de facto* ownership of the land.

There are also several institutional factors not easily quantified that may have an impact on forest cover dynamics in Guatemala. Several authors argue that the institutions with responsibility to manage Guatemala's forests are weak, with low budgets, and with low degree of cooperation and coordination among them (Castañeda and Sandoval, 2008; Ortega et al., 2008; Universidad Rafael Landivar et al, 2009). They further state that insufficient resources and inadequate management tools for controlling illegal deforestation results in limited effect of the legal framework. The alleged inadequate management may have an impact at the national level, and at lower levels, through local initiatives and management regimes. The expansion of drug-trafficking related activities in remote areas may further complicate the effective governance of forest resources. Large areas of El Petén for example are currently controlled by Mexican and Guatemalan drug cartels (Bull and Berge, 2009; Pacheco et al., forthcoming).

Additional observations

By removing explanatory variables that were strongly correlated in the study, the confounding effect of these associations was eliminated. Yet the causes behind forest cover change are probably influenced by some explanatory variables causing changes in other explanatory variables, thereby indirectly affecting the response variable (Wright, 1921; Wright, 1923). A path analysis may be a possible approach to estimate the effect of each of the linked paths of variables resulting in forest cover change (Wright, 1921); however the complexity of the method prevented this from being carried out in this study.

The limited knowledge of the quality of the data included is a challenge when using a meta-analysis approach. Particularly relevant for this study is the database on forest cover, which is under current revision. The revised data will be available in December 2010, also including data from 1986 until 2006. The longer time period included in the revised database will enable analysis with improved ability to measure variables acting on long temporal scales, experiencing short term flexibility, and to a larger extent include the effect of possible delays in response (Deacon, 1994; Perz, 2007).

With the revision of the forest report, data on forest cover for a 20-year period from 1986 to 2006 will be available. The extended temporal scale of the data series can be followed by including data on the explanatory variables from within the same period of time, thereby providing more accurate and conclusive results with lower sensitivity to short time variation.

Conclusion

This study aimed to indicate some of the main drivers behind forest cover change in Guatemala. The findings revealed distinct links between five of the included variables and forest cover change. Higher deforestation was found in areas with low forest cover, contradictory to the general conclusion from the literature. Since this also implies that areas with high forest cover experience low deforestation rates, the relationship may indicate that larger continuous areas with forest are more likely to be conserved, which for example is positive for the conservation of species requiring large areas for existence. However, for people living in areas where already is already low; access to forest related resources may become even more limited in the future.

Of the variables that appeared to have the most distinct link to low deforestation rates were four variables that can all be related to development: (i) high proportion urban population, (ii) high densities of paved road, (iii) low extreme poverty levels, and (iv) low proportion of the economically active population working in agriculture. The link with development is interesting in the light of Guatemala being a developing country with challenges like poverty and social inequality receiving ample attention by the national government and the international society. If reducing deforestation rates and improving development is corresponding, the country has the opportunity to continue development without compromising their natural environment. Guatemala may actually be undergoing a forest transition that over time will lead to a halt in deforestation rates and eventually reforestation. Even if the current deforestation rates are high, the observed trends may be one of the first signs of a transition in forest cover change in Guatemala, and this gives promising prospects for the future of the forests. However, most of the country is experiencing deforestation rather than reforestation, and at the national level the country still exhibits high deforestation rates. Reducing this trend of forest loss and improve forest conservation requires initiatives and management actions.

Explicit cause-effect relationships across all levels were not distinguished in this study, adding weight to the theory that causes behind forest cover change are complex, context dependent, and site specific. In order to deal with site specific dynamics, the forest management initiatives need to consider the particular environmental, - socio-economic, - and political context of the area. The findings in this study both confirm and contradict findings in the literature, yet the literature in itself is often contradictory in regards to the effect of the various variables. This gives further support to the theory that the causes behind forest cover change are site specific.

The analysis employed in this study has not been able to fully explore the complex associations leading to forest cover change; the probable intricate relationships between the exploratory variables causing an effect on the response variable can only be speculated upon. Future studies are recommended to resort to more complex methods for exploration of the associations in order to establish potential paths of causation leading to an effect on forest cover change.

Literature list

- Alwang, J., P. B. Siegel, and D. Wooddall-Gainey.** 2005. Spatial Analysis of Rural Economic Growth Potential in Guatemala. Latin America and Caribbean Region. Environmentally and Socially Sustainable Development Department. Sustainable Development Working Paper No 21. World Bank.
- Andam, K. S., P. J. Ferraro, A. Pfaff, G. A. Sanchez-Azofeifa, and J. A. Robalino.** 2008. Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences of the United States of America* **105**(42): 16089-16094.
- Angelsen, A. and D. Kaimowitz.** 1999. Rethinking the causes of deforestation: Lessons from economic models. *World Bank Research Observer* **14**(1): 73-98.
- Angelsen, A. and S. Wunder.** 2003. Exploring the forest - poverty link: key concepts, issues and research implications. Occasional Paper no. 40. Center for International Forestry Research (CIFOR), Bogor, Indonesia.
- Angelsen, A.** 2007. Forest cover change in space and time: combining the von Thünen and forest transition theories. World Bank Policy Research Working Paper 4117.
- Arriagada, C.** 2000. La pobreza en América Latina: nuevos escenarios y desafíos de políticas para el hábitat urbano. CEPAL. Serie Medio Ambiente y Desarrollo No 27. Santiago de Chile, Chile.
- Bangert-Drowns, R. L. and Rudner, L. M.** 1991. Meta-analysis in educational research. ERIC Digest. *Practical Assessment, Research & Evaluation*, **2**(8). Published December 1991, retrieved August 16, 2010 from <http://www.eric.ed.gov/PDFS/ED339748.pdf>
- Barbier, E. B., J. C. Burgess, and A. Grainger.** 2010. The forest transition: Towards a more comprehensive theoretical framework. *Land Use Policy* **27**(2): 98-107.
- Baumeister, E.** 2003. Tierra, Empleo e Ingresos de la Población Rural en Guatemala. Serie de Cuadernos de Desarrollo Humano No 2002-8. PNUD Guatemala. P. 26.
- Bensel, T.** 2008. Fuelwood, deforestation, and land degradation: 10 years of evidence from cebu province, the Philippines. *Land Degradation & Development* **19**(6): 587-605.

- Bhatt, B. P. and M. S. Sachan.** 2004. Firewood consumption along an altitudinal gradient in mountain villages of India. *Biomass and Bioenergy* **27**(1): 69-75.
- Bilsborrow, R. E. and P. F. DeLargy.** 1990. Land use, migration, and natural resource deterioration: The experience of Guatemala and the Sudan. *Population and Development Review* **16**: 125-147.
- Bond, I., M. Grieg-Gran, S. Wertz-Kanounnikoff, P. Hazlewood, S. Wunder, and A. Angelsen.** 2009. Incentives to sustain forest ecosystem services: A review and lessons for REDD. London, UK.
- Bonham, C. A., E. Sacayon, and E. Tzi.** 2008. Protecting imperiled "paper parks": potential lessons from the Sierra Chinajai, Guatemala. *Biodiversity and Conservation* **17**(7): 1581-1593.
- Brea, J. A.** 2003. Population dynamics in Latin America. *Population Bulletin* **58**(1): 3-36.
- Bull, B. and Berge, E.** 2009. The forgotten wave of violence. Norwegian Latin America Research Network. Published April 14, 2009, retrieved August 16, 2010 from http://www.norlarnet.uio.no/pdf/behind-the-news/englis/Wave_of_violence_english.pdf
- Burns, T. J., E. L. Kick, D. A. Murray, and D. A. Murray.** 1994. Demography, development and deforestation in a world-system perspective. *International Journal of Comparative Sociology* **35**(3-4): 221-239.
- Carey, C., N. Dudley, and S. Stolton.** 2000. Squandering Paradise? The Importance and Vulnerability of the World's Protected Areas. WWF-World Wide Fund for Nature. Gland, Switzerland.
- Carr, D. L.** 2005. Forest Clearing Among Farm Households in the Maya Biosphere Reserve. *The Professional Geographer* **57**(2): 157-168.
- Carr, D. L.** 2008. Farm households and land use in a core conservation zone of the Maya Biosphere Reserve, Guatemala. *Human Ecology* **36**(2): 231-248.
- Cayuela, L., J. M. R. Benayas, and C. Echeverría.** 2006. Clearance and fragmentation of tropical montane forests in the Highlands of Chiapas, Mexico (1975-2000). *Forest Ecology and Management* **226**(1-3): 208-218.

Chomitz, K. M. 2007. At Loggerheads? Agricultural Expansion, Poverty Reduction, and Environment in the Tropical Forests. A World Bank Policy Research Report. Washington, D.C., USA.

Chomitz, K. M. and D. A. Gray. 1996. Roads, Land Use, and Deforestation: A Spatial Model Applied to Belize. *World Bank Econ Rev* **10**(3): 487-512.

Chowdhury, R. R. 2006. Driving forces of tropical deforestation: The role of remote sensing and spatial models. *Singapore Journal of Tropical Geography* **27**(1): 82-101.

Coffin, A. W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. *Journal of Transport Geography* **15**(5): 396-406.

CONAP (Consejo Nacional de Áreas Protegidas). 2003. Informe Nacional de Áreas Protegidas de Guatemala. Guatemala City, Guatemala.

CONAP (Consejo Nacional de Áreas Protegidas). 2009a. Diagnóstico de la conservación y manejo de recursos naturales en tierras comunales. Guatemala City, Guatemala.

CONAP (Consejo Nacional de Áreas Protegidas). 2009b. Diversidad de ecosistemas en Guatemala. Guatemala City, Guatemala.

Contreras-Hermosilla, A. 2000. The underlying causes of forest decline. Center for International Forestry Research (CIFOR). Occasional paper no. 30. Bogor, Indonesia.

Crawley, M. J. 2007. The R book. John Wiley & Sons Ltd. West Sussex, England.

Crk, T., M. Uriarte, F. Corsi, and D. Flynn. 2009. Forest recovery in a tropical landscape: what is the relative importance of biophysical, socioeconomic, and landscape variables? *Landscape Ecology* **24**(5): 629-642.

Lovell, W. G. 1985. Conquest and Survival in colonial Guatemala – a Historical Geography of the Cuchumatán Highlands, 1500-1821. McGill-Queen's University Press. Kingston, UK.

Deacon, R. T. 1994. Deforestation and the rule of law in a cross-section of countries. *Land Economics* **70**(4): 414-430.

Dharmaratne, G. S., F. Yee Sang, and L. J. Walling. 2000. Tourism potentials for financing protected areas. *Annals of Tourism Research* **27**(3): 590-610.

Deininger, K. W. and B. Minten. 1999. Poverty, policies, and deforestation: The case of Mexico. *Economic Development and Cultural Change* **47**(2): 313-344.

Del Popolo, F. y A. M. Oyarce. 2005. Población indígena de América Latina: perfil sociodemográfico en el marco de la Conferencia Internacional sobre la Población y el Desarrollo y de las Metas del Milenio. In *Pueblos indígenas y afrodescendientes de América Latina y el Caribe: información sociodemográfica para políticas y programas*, 27 al 29 de abril de 2005, Santiago de Chile, Chile.

DeMontalembert, M. R., J. Clement. 1983. Fuelwood Supplies in the Developing Countries. FAO Forestry Paper No. 42. Food and Agriculture Organization of the United Nations, Rome, Italy.

Dourojeanni, M.J. 1999. The Future of the Latin American Natural Forests. Inter-American Development Bank. Environment Division Working Paper. Washington D.C, USA.

Ehrhardt-Martinez, K., E. M. Crenshaw, and J. Craig Jenkins 2002. Deforestation and the environmental Kuznets curve: A cross-national investigation of intervening mechanisms. *Social Science Quarterly* **83**(1): 226-243.

Eken, G., L. Bennun, T. M. Brooks, W. Darwall, L. D. C. Fishpool, M. Foster, D. Knox, P. Langhammer, P. Matiku, E. Radford, P. Salaman, W. Sechrest, M. L. Smith, S. Spector, and A. Tordoff. 2004. Key biodiversity areas as site conservation targets. *Bioscience* **54**(12): 1110-1118.

Ellison-Loschmann, L. and N. Pearce. 2006. Improving access to health care among New Zealand's Maori population. *American Journal of Public Health* **96**(4): 612-617.

Elías, S., G. Gellert, E. Pape, y E. Reyes. 1997. Evaluación de la sostenibilidad: el caso de Guatemala. Facultad Latinoamericana de Ciencias Sociales & World Wildlife Fund. Guatemala City, Guatemala.

Elías, S., A. Larson, y J. Mendoza. 2009. Tenencia de la tierra, bosques y medios de vida en el altiplano occidental de Guatemala. Centro Internacional de Investigaciones Forestales (CIFOR), Programa de Estudios Rurales y Territoriales (PERT) de la Facultad de Agronomía, Universidad de San Carlos de Guatemala. Guatemala City, Guatemala.

- Ervin, J.** 2003. Protected Area Assessments in Perspective. *Bioscience* **53**(9): 819-822.
- Ewers, R. M.** 2006. Interaction effects between economic development and forest cover determine deforestation rates. *Global Environmental Change-Human and Policy Dimensions* **16**(2): 161-169.
- FAO (Food and Agriculture Organization of the United Nations).** 2000. Global Forest Resource Assessment 2000. FAO Forestry Paper 140. Rome, Italy.
- FAO (Food and Agriculture Organization of the United Nations).** 2006. Global Forest Resources Assessment 2005. Progress towards sustainable forest management. Rome, Italy.
- Fearnside, P. M.** 2008. The Roles and Movements of Actors in the Deforestation of Brazilian Amazonia. *Ecology and Society* **13**(1).
- Ferroukhi, L. (ed.).** 2003. La Gestión Forestal Municipal en América Latina. Centro Internacional de Investigaciones Forestales (CIFOR). Bogor, Indonesia.
- Figuroa, F., V. Sanchez-Cordero, and I. Trejo.** 2009. Socioeconomic context of land use and land cover change in Mexican biosphere reserves. *Environmental Conservation* **36**(3): 180-191.
- Freitas, S. R., T. J. Hawbaker, and J. P. Metzger.** 2010. Effects of roads, topography, and land use on forest cover dynamics in the Brazilian Atlantic Forest. *Forest Ecology and Management* **259**(3): 410-417.
- Garcia-Frapolli, E., G. Ramos-Fernandez, E. Galicia, and A. Serrano.** 2009. The complex reality of biodiversity conservation through Natural Protected Area policy: Three cases from the Yucatan Peninsula, Mexico. *Land Use Policy* **26**(3): 715-722.
- Geist H. J. and E. F. Lambin.** 2001. What Drives Tropical Deforestation? A meta-analysis of proximate and underlying causes of deforestation based on sub-national case study evidence. LUCS Report Series No. 4. LUCS International Project Office Louvain-la-Neuve, Belgium.
- Geist, H. J. and E. F. Lambin.** 2002. Proximate Causes and Underlying Driving Forces of Tropical Deforestation. *Bioscience* **52**(2): 143-150.

- Gibson, C. G., F. E. Lehoucq, and J. T. Williams.** 2002. Does Privatization Protect Natural Resources? Property Rights and Forests in Guatemala. *Social Science Quarterly* **83**(1):206-225.
- Gomez, L.** 2008. Áreas protegidas, entre invaciones e ingobernabilidad 2008. Universidad de San Carlos de Guatemala. Guatemala City, Guatemala.
- Gould, K. A.** 2006. Land regularization on agricultural frontiers: The case of Northwestern Peten, Guatemala. *Land Use Policy* **23**(4): 395-407.
- Green, G. M. and R. W. Sussman** 1990. Deforestation history of the eastern rain forests of Madagascar from satellite images. *Science* **248**(4952): 212-215.
- Hall, G. and H.A. Patrinos (ed.).** 2006. Indigenous Peoples, Poverty and Human Development in Latin America: 1994-2004. New York, USA.
- Heinen, J. T.** 2010. The Importance of a Social Science Research Agenda in the Management of Protected Natural Areas, with Selected Examples. *Botanical Review* **76**(2): 140-164.
- Heltberg, R.** 2003. Household Fuel Use and Fuel Switching in Guatemala. Oil and Gas Policy Division, the World Bank.
- Honey-Rosés, J.** 2009. Disentangling the proximate factors of deforestation: The case of the Monarch butterfly Biosphere Reserve in Mexico. *Land Degradation & Development* **20**(1): 22-32.
- International Energy Agency (IEA).** 2006. Chapter 15: Energy for Cooking in Developing Countries *in World Energy Outlook 2006 Edition*. Paris, France.
- International Labour Office (ILO).** 2008. Promotion of rural employment for poverty reduction. Report IV, International Labour Conference, 97th Session. Geneva, Switzerland.
- The National Bureau of Statistics (Instituto Nacional de Estadística, INE).** 1996. X Censo Nacional de Población y V de Habitación. República de Guatemala.
- The National Bureau of Statistics (Instituto Nacional de Estadística, INE).** 2005. Lugares Poblados , XI Censo Nacional de Población y VI de Habitación 2002. República de Guatemala.

The National Forestry Institute (Instituto Nacional de Bosques, INAB). 2006. Boletín de Estadística Forestal 1999-2004.

The National Geographic Bureau of Guatemala (Instituto Geográfico Nacional, IGN). 2003. Las carreteras año 2003.

Jaramillo, C. F. and T. Kelly. 1997. Deforestation and property rights in Latin America. The Inter-American Development Bank, Working paper (Dec.): 1-40.

Jha, S. and K. S. Bawa. 2006. Population growth, human development, and deforestation in biodiversity hotspots. *Conservation Biology* **20**(3): 906-912.

Jones, J. R. 1990. Colonization and Environment: Land Settlement Projects in Central America. United Nations University Press, Tokyo, Japan.

Jorgenson, A. K. 2006. Unequal ecological exchange and environmental degradation: A theoretical proposition and cross-national study of deforestation, 1990-2000. *Rural Sociology* **71**(4): 685-712.

Kaimowitz, D. 1996. Livestock and Deforestation in Central America in the 1980s and 1990s: A Policy Perspective. Center for International Forestry Research. Bogor, Indonesia.

Kaimowitz, D. 1997. Factors determining low deforestation: The Bolivian Amazon. *Ambio* **26**(8): 537-540.

Kaimowitz, D. and A. Angelsen. 1998. Economic Models of Tropical Deforestation. A Review. Center for International Forestry Research (CIFOR). Bogor, Indonesia.

Kaimowitz, D. 2008. The prospects for Reduced Emissions from Deforestation and Degradation (REDD) in Mesoamerica. *International Forestry Review* **10**(3): 485-495.

Katz, E. G. 2000. Social capital and natural capital: A comparative analysis of land tenure and natural resource management in Guatemala. *Land Economics* **76**(1): 114-132.

Keys, E. and W. J. McConnell. 2005. Global change and the intensification of agriculture in the tropics. *Global Environmental Change-Human and Policy Dimensions* **15**(4): 320-337.

- Klooster, D.** 2003. Forest transitions in Mexico: Institutions and forests in a globalized countryside. *Professional Geographer* **55**(2): 227-237.
- Koop, G. and L. Tole.** 2001. Deforestation, distribution and development. *Global Environmental Change* **11**(3): 193-202.
- Kramer, R. and C.P. van Schaik.** 1997. Preservation paradigms and tropical rain forests. In R. Kramer, C. van Schaik and J. Johnson, Editors, *Last Stand: Protected Areas and the Defense of Tropical Biodiversity*. Oxford University Press, New York, USA.
- Lambin, E. F., H. J. Geist, and E. Lepers.** 2003. Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources* **28**(1): 205-241.
- Laurance, W. F., A. K. M. Albernaz, G. Schroth, P. M. Fearnside, S. Bergen, E. M. Venticinque, and S. Da Costa.** 2002. Predictors of deforestation in the Brazilian Amazon. *Journal of Biogeography* **29**(5-6): 737-748.
- Lesschen, J. P., P. H. Verburg, S. J. Staal.** 2005. Statistical methods for analysing the spatial dimension of changes in land use and farming systems. LUCC Report Series 7. Land-Use and Land-Cover Change (LUCC) Project. International Human Dimensions Programme on Global Environmental Change (IHDP). International Geosphere-Biosphere Programme (IGBP). Nairobi, Kenya and Wageningen, the Netherlands.
- Lewis, C.** 1996. Managing Conflicts in protected areas. IUCN (The World Conservation Union). Gland, Switzerland.
- Loening, L.J. and M. Markussen.** 2003. Pobreza, deforestación y sus eventuales implicaciones para la biodiversidad de Guatemala. *Economía, Sociedad y Territorio* **4**(14):279-315.
- Lopez, R. and G. L. Galinato.** 2005. Trade policies, economic growth, and the direct causes of deforestation. *Land Economics* **81**(2): 145-169.
- Lozano, V.** 2005. Encuesta nacional sobre emigración internacional de guatemaltecos 2002-2003. *Población y Salud en Mesoamérica* num. enero-junio.

Macht, C., W. G. Axinn, and D. Ghimire. 2007. Household energy consumption: community context and the fuelwood transition. Population Studies Center Research Report 07-629, University of Michigan, USA.

Macours, K. 2009. Land Titles and Conflicts in Guatemala. Inter-American Development Bank. Working paper.

MAGA (Ministerio de Agricultura, Ganadería y Alimentación). 1999. Política agraria de Guatemala. Guatemala City, Guatemala.

MAGA (Ministerio de Agricultura, Ganadería y Alimentación). 2000. Mapa digital de Áreas Protegidas. Laboratorio de Información Geográfica del MAGA (SIG-MAGA). Guatemala City, Guatemala.

MAGA (Ministerio de Agricultura, Ganadería y Alimentación). 2002. Atlas Temático de la República de Guatemala. Laboratorio de Información Geográfica del MAGA (SIG-MAGA). Guatemala City, Guatemala.

Marrone, S. 2007. Understanding barriers to health care: A review of disparities in health care services among indigenous populations. *International Journal of Circumpolar Health* **66**(3): 188-198.

Mather, A. S. 1992. The forest transition. *Area* **24**(4): 367-379.

Mather, A. S. and C. L. Needle. 1998. The forest transition: a theoretical basis. *Area* **30**(2): 117-124.

Mather, A. S. and C. L. Needle. 1997. Trends in global forest cover: issues in explanation and modelling. In Himiyama, Y. and Crissman, L. (eds) *Information bases for land use/cover change research*. Asahikawa, Japan.

Mather, A. S. and C. L. Needle. 1999. Development, democracy and forest trends. *Global Environmental Change-Human and Policy Dimensions* **9**(2): 105-118.

Mather, A. S. and C. L. Needle. 2000. The relationships of population and forest trends. *Geographical Journal* **166**: 2-13.

Mauro, A. and M. Merlet. 2003. Acceso a la tierra y reconocimiento de los derechos sobre la tierra en Guatemala. Coalición Internacional para el acceso a la tierra. Roma, Italia

Meentzen, A. 2001. Estrategias de desarrollo culturalmente adecuadas para mujeres indígenas. Banco Interamericano de Desarrollo. Unidad de Pueblo Indígenas y Desarrollo Comunitario, Departamento de Desarrollo Sostenible. Washington D.C., USA.

Melgar W. 2003. Estado de la diversidad biológica de los árboles y bosques de Guatemala. Servicio de Desarrollo de Recursos Forestales, Documento de Trabajo FGR/53S. Food and Agriculture Organization (FAO). Rome, Italia.

Mertens, B., W. D. Sunderlin, and N. Ousseynou. 2000. Impact of Macroeconomic Change on Deforestation in South Cameroon: Integration of Household Survey and Remotely-Sensed Data. *World Development* **28**(6): 983-999.

Mohammad, A. G. and M. A. Adam. 2010. The impact of vegetative cover type on runoff and soil erosion under different land uses. *Catena* **81**(2): 97-103.

Munroe, D. K., J. Southworth, and C. M. Tucker. 2002. The dynamics of land-cover change in western Honduras: exploring spatial and temporal complexity. *Agricultural Economics* **27**(3): 355-369.

Myers, N. 1991. Tropical forests – present status and future outlook. *Climatic Change* **19**(1-2): 3-32.

Nagendra, H., S. Paul, S. Pareeth, and S. Dutt. 2009. Landscapes of Protection: Forest Change and Fragmentation in Northern West Bengal, India. *Environmental Management* **44**(5): 853-864.

Nepstad, D., S. Schwartzman, B. Bamberger, M. Santilli, D. Ray, P. Schlesinger, P. Lefebvre, A. Alencar, E. Prinz, G. Fiske, and A. Rolla. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conservation Biology* **20**(1): 65-73.

Ochoa-Gaona, S. and M. González-Espinosa. 2000. Land use and deforestation in the highlands of Chiapas, Mexico. *Applied Geography* **20**(1): 17-42.

Ortega, P., A. García-Guerrero, C. A. Ruíz, J. Sabogal, and J.D. Vargas (eds.). 2010. Deforestación Evitada. Una Guía REDD + Colombia. Ministerio de Ambiente, Vivienda y Desarrollo Territorial; Conservación Internacional Colombia; Fondo Mundial para la Naturaleza (WWF); The Nature Conservancy; Corporación Ecovera; Fundación Natura; Agencia de Cooperación Americana (USAID). Bogotá, Colombia.

Ostrom, E., J. Burger, C. F. Field, R. B. Norgaard, and D. Policansky. 1999. Revisiting the Commons: Local Lessons, Global Challenges. *Science* **284**(5412): 278-282.

Pacheco, P., M. Aguilar-Støen, J. Börner, A. Etter, L. Putzel, and M. C. Vera Diaz. Forthcoming. Landscape transformation in tropical Latin America. Assessing trends and policy implications for REDD+.

Parrotta, J. A. and M. Agnoletti. 2007. Traditional forest knowledge: Challenges and opportunities. *Forest Ecology and Management* **249**(1-2): 1-4.

Pearce, D. W. and K. Brown. 1994. *The Causes of Tropical Deforestation.* University College London Press, UK.

Perz, S. G. 2007. Grand theory and context-specificity in the study of forest dynamics: Forest transition theory and other directions. *Professional Geographer* **59**(1): 105-114.

Perz, S. G., L. Cabrera, L. A. Carvalho, J. Castillo, and G. Barnes. 2010. Global Economic Integration and Local Community Resilience: Road Paving and Rural Demographic Change in the Southwestern Amazon. *Rural Sociology* **75**(2): 300-325.

Pijanowski, B. C., L. R. Iverson, A. C. Drew, H. N. N. Bulley, J. M. Rhemtulla, M. C. Wimberly, A. Bartsch, and J. Peng. 2010. Addressing the interplay of poverty and the ecology of landscapes: a Grand Challenge Topic for landscape ecologists? *Landscape Ecology* **25**(1): 5-16.

Plant, R. 1995. *Rebuilding Civil Society: Rural Workers' Organizations in Guatemala.* International Labour Office. Development and Technical Cooperation Department. Geneva, Switzerland.

Plant, R. 1998. *Indigenous Peoples and Poverty Reduction. A Case Study of Guatemala.* Indigenous Peoples and Community Development Unit. Inter-American Development Bank. Sustainable Development Department.

Population Reference Bureau (PRB). 2009. World population data sheet. Washington D.C., USA.

Questconnect. 2010. Map showing the 22 departments of Guatemala. Retrieved August 19, 2010 from http://www.questconnect.org/images/guat_departs1.jpg

Ramankutty, N. and J. A. Foley. 1999. Estimating historical changes in global land cover: Croplands from 1700 to 1992. *Global Biogeochemical Cycles* **13**(4): 997-1027.

Redford, K. H. and A. M. Stearman. 1993. Forest-Dwelling Native Amazonians and the Conservation of Biodiversity: Interests in Common or in Collision? *Conservation Biology* **7**(2): 248-255.

Richards, M. 1997. Common Property Resource Institutions and Forest Management in Latin America. *Development and Change* **28**(1): 95-117

Rivadeneira, L. 2001. Guatemala: población y desarrollo. Un diagnostico sociodemográfico. CEPAL/ECLAC, ONU. Santiago de Chile, Chile.

Rodrigues, A. S. L., H. R. Akcakaya, S. J. Andelman, M. I. Bakarr, L. Boitani, T. M. Brooks, J. S. Chanson, L. D. C. Fishpool, G. A. B. Da Fonseca, K. J. Gaston, M. Hoffmann, P. A. Marquet, J. D. Pilgrim, R. L. Pressey, J. Schipper, W. Sechrest, S. N. Stuart, L. G. Underhill, R. W. Waller, M. E. J. Watts, and X. Yan. 2004. Global gap analysis: Priority regions for expanding the global protected-area network. *Bioscience* **54**(12): 1092-1100.

Rosero-Bixby, L. and A. Palloni. 1998. Population and deforestation in Costa Rica. *Population and Environment* **20**(2): 149-185.

R-project. 2010. Software R, version 2.11.1. The R Foundation for Statistical Computing. Released on 31.05.2010, downloaded 23.06.2010 from: <http://www.r-project.org>

Rudel, T. and J. Roper. 1997. Forest Fragmentation in the Humid Tropics: A Cross-National Analysis. *Singapore Journal of Tropical Geography* **18**(1): 99-109.

Rudel, T. K., O. T. Coomes, E. Moran, F. Achard, A. Angelsen, J. Xu, and Eric Lambin. 2005. Forest transitions: towards a global understanding of land use change. *Global Environmental Change-Human and Policy Dimensions* **15**(1): 23-31.

Rudel, T. K, R. Defries, G. P. Asner, and W. F. Laurance. 2009. Changing Drivers of Deforestation and New Opportunities for Conservation. *Conservation Biology* **23**(6): 1396-1405.

Sader, S. A., T. Sever, J. C Smoot, and M. Richardsl. 1994. Forest change estimates for the northern Peten region of Guatemala - 1986-1990. *Human Ecology* **22**(3): 317-332.

Segovia, A. 2004. Centroamerica despues del cafe: el fin del modelo agroexportador tradicional y el surgimiento de un nuevo modelo. *Revista Centroamericana de Ciencias Sociales* **2**(1):5-38

Shandra, J. M. 2007. Economic dependency, repression, and deforestation: A quantitative, cross-national analysis. *Sociological Inquiry* **77**(4): 543-571.

Shriar, A. J. 2002. Food security and land use deforestation in northern Guatemala. *Food Policy* **27**(4): 395-414.

Siren, A. H. 2007. Population growth and land use intensification in a subsistence-based indigenous community in the Amazon. *Human Ecology* **35**(6): 669-680.

Skole, D. and C. Tucker. 1993. Tropical deforestation and habitat fragmentation in the Amazon – satellite data from 1978 to 1988. *Science* **260**(5116): 1905-1910.

Solórzano, J. D. T. and M. Del Cid. 2003. Decent Work and the informal economy in Central America. Working paper no. 7. International Labour Office. Policy Integration department. Geneva, Switzerland.

Southgate, D. and M. Basterrechea. 1992. Population growth, public policy and resource degradation: The case of Guatemala. *Ambio* **21**(7): 460-464.

Southworth, J. and C. Tucker. 2001. The influence of accessibility, local institutions, and socioeconomic factors on forest cover change in the mountains of western Honduras. *Mountain Research and Development* **21**(3): 276-283.

Stocks, A. B McMahan, and P. Taber. 2007. Indigenous, colonist, and government impacts on Nicaragua's Bosawas reserve. *Conservation Biology* **21**(6): 1495-1505.

Tripatlas. 2010. Map showing the situation of Guatemala in the world. Retrieved August 19, 2010 from http://diamondgroupnetwork.com/info/images/image_map/big/LocationGuatemala.svg.png

- Tucker, C.** 1999. Common property design principles and development in a Honduran community. *The Fletcher Journal of Development Studies* **14**: 1-23.
- Tucker, C. M., J. C. Randolph, and E. J. Castellanos.** 2007. Institutions, biophysical factors and history: An integrative analysis of private and common property forests in Guatemala and Honduras. *Human Ecology* **35**(3): 259-274.
- Tucker, C. M., J. C. Randolph, T. Evans, K. P. Andersson, L. Persha, and G. M. Green.** 2008. An Approach to Assess Relative Degradation in Dissimilar Forests: Toward a Comparative Assessment of Institutional Outcomes. *Ecology and Society* **13**(1).
- Turner, D. P., G. Koerper, H. Gucinski, C. Peterson, and R. K Dixon.** 1993. Monitoring global change - comparison of forest cover estimates using remote-sensing and inventory approaches. *Environmental Monitoring and Assessment* **26**(2-3): 295-305.
- Tucker, C. M., D. K. Munroe, H. Nagendra, and J. Southworth.** 2005. Comparative Spatial Analyses of Forest Conservation and Change in Honduras and Guatemala. *Conservation and Society* **3**(1):174–200.
- (UN) United Nations.** 2002. World Urbanization Prospects: the 2001 Revision. Data Tables and Highlights. Department of Economic and Social Affairs, Population Division. New York, USA.
- (UN) United Nations.** 2004. World Urbanization Prospects: the 2003 Revision. Department of Economic and Social Affairs, Population Division. New York, USA.
- (UN) United Nations.** 2005. The Millennium Development Goals Report 2005. New York, USA.
- UNDP (United Nations Development Programme).** 2005. Diversidad étnico-cultural: la ciudadanía en un estado plural: Informe Nacional de Desarrollo Humano. Programa de las Naciones Unidas para el Desarrollo. Guatemala City, Guatemala.
- Universidad Rafael Landívar.** 1987. Perfil Ambiental de la Republica de Guatemala. Instituto de ciencias ambientales y agrícola (ICATA). Guatemala City, Guatemala.
- Universidad Rafael Landívar, Instituto de Agricultura, Recursos Naturales y Ambiente (IARNA).** 2006. Perfil ambiental de Guatemala 2006. Guatemala City, Guatemala.

Universidad Rafael Landívar, Instituto de Agricultura, Recursos Naturales y Ambiente (IARNA). 2009. Contexto de las prácticas ilegales en el sector forestal de Guatemala. Proyecto ECIAF. Guatemala City, Guatemala.

Universidad del Valle de Guatemala (UVG), Instituto Nacional de Bosques (INAB), y Consejo Nacional de Áreas Protegidas (CONAP). 2006. Dinámica de la cobertura Forestal de Guatemala durante los años 1991, 1996 y 2001 y Mapa de Cobertura Forestal 2001: Fase II: Dinámica de la cobertura forestal. Guatemala City, Guatemala.

Vakis, R. 2003. Guatemala: Livelihoods, Labor Markets, and Rural Poverty. Guatemala Poverty Assessment (GUAPA) program technical paper no. 1. Background paper for Guatemala Poverty Assessment (GUAPA). World Bank. Washington D.C., USA.

Vanclay, J. K. 1993. Saving the tropical forest – needs and prognosis. *Ambio* **22**(4): 225-231.

Verolme, H. J. H. and J. Moussa. 1999. Addressing the underlying causes of deforestation and forest degradation - Case studies, analysis and policy recommendations. Biodiversity Action Network. Washington, D.C.

World Bank. 1995. Guatemala, tenencia agraria y manejo de los recursos naturales. División de Recursos Naturales Departamento II. Oficina Regional para América Latina y el Caribe.

World Bank. 2002a. Country assistance strategy progress report for the republic of Guatemala. Central American Country Management Unit. Latin American and the Caribbean Regional Office. Washington D.C., USA.

World Bank. 2002b. Guatemala: Country Assistance Evaluation. Operations Evaluation Department. Washington D.C., USA.

World Bank. 2003. Poverty in Guatemala. Washington D.C., USA.

World Bank. 2004. Drivers of sustainable rural growth and poverty reduction in Central America. Guatemala case study. Volume I: Executive summary and main text. Department of Environmentally and Socially Sustainable Development. Latin America and the Caribbean Region.

Wright, S. J. and M. J. Samaniego. 2008. Historical, Demographic, and Economic Correlates of Land-Use Change in the Republic of Panama. *Ecology and Society* **13**(2): 21.

Wright, S. 1921. Correlation and causation. *Journal of Agricultural Research* **20**: 557-585.

Wright, S. 1934. The method of path coefficients. *Annals of Mathematical Statistics* **5**: 161-215.

Wunder, S. 1996. Deforestation and the Uses of Wood in the Ecuadorian Andes. *Mountain Research and Development* **16**(4): 367-381.

Zwane, A. P. 2007. Does poverty constrain deforestation? Econometric evidence from Peru. *Journal of Development Economics* **84**(1): 330-349.

Appendices

Appendix 1. Correlated explanatory variables at department level

Correlated explanatory variables at department level (p-value <0.05)		r
Population growth	All types of roads	0.43
Population growth	Initial forest cover	-0.66
Population growth	Paved roads	-0.21
Urbanization	Extreme poverty	-0.52
Urbanization	Indigenous population	-0.68
Extreme poverty levels	Indigenous population	0.48
Extreme poverty levels	Use of firewood	0.7
Extreme poverty levels	Communal lands	0.45
Extreme poverty levels	Paved roads	-0.44
HDI change	Indigenous population	-0.47
Indigenous population	Use of firewood	0.57
Use of firewood	Working in agriculture	0.72
Use of firewood	Paved roads	-0.47
Working in agriculture	Paved roads	-0.65
Working in agriculture	All types of roads	-0.47
Protected areas	All types of roads	-0.43
Protected areas	Initial forest cover	0.51
Communal land	Slope	0.44
Communal land	Paved roads	-0.48
Paved roads	All types of roads	0.50

Appendix 2. Correlated explanatory variables at municipality level

Correlated explanatory variables at municipality level (p-value <0.05)		r
Population growth	Indigenous population	-0.31
Population growth	Urbanization	0.26
Population growth	Paved roads	-0.21
Population growth	Protected area	-0.41
Population growth	Working in agriculture	0.3
Urbanization	Initial forest cover	-0.3
Extreme poverty levels	Use of firewood	0.52
Extreme poverty levels	Working in agriculture	0.27
Extreme poverty levels	Paved roads	-0.33
Extreme poverty levels	Protected areas	-0.26
Extreme poverty levels	Slope	0.30
Extreme poverty levels	Initial forest cover	0.20
HDI change	Indigenous population	-0.45
HDI change	Use of firewood	-0.2
HDI change	Protected areas	-0.36
HDI change	Slope	-0.25
Indigenous population	Use of firewood	0.23
Indigenous population	Working in agriculture	-0.32
Indigenous population	Slope	0.38
Indigenous population	Protected areas	0.51
Indigenous population	Communal lands	0.21
Use of firewood	Working in agriculture	0.55
Use of firewood	Slope	0.44
Use of firewood	Paved roads	-0.38
Use of firewood	All types of roads	-0.22
Working in agriculture	Protected areas	-0.22
Working in agriculture	Communal lands	-0.3
Working in agriculture	Slope	0.18
Working in agriculture	Paved roads	-0.47
Working in agriculture	All types of roads	-0.43
Protected areas	Slope	0.3
Protected areas	Paved roads	0.42
Slope	Initial forest cover	0.23
Paved roads	All types of roads	0.33
Paved roads	Initial forest cover	-0.21
All types of roads	Initial forest cover	-0.25