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Analysis of forest degradation and its underlying causes in the Toledo district of Belize

By

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DEDICATION

This Thesis is dedicated to my father, Martin St. Luce, who has always been my inspiration. Thank you so much daddy for believing in me.

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- I would first want to acknowledge my ever living savor and creator of all, Heavenly Father Yahweh, for giving me strength and health, to commence and finalize this memorable stage in my life.

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BIOGRAPHY

The author, Hannah St. Luce Martinez, was born to Martin and Marcella St. Luce in the country of Dominica on the 14th of December 1978. Her parents always considered her a child with love for the outdoors and a warm heart that made each and every one in her village her friend.

She attended the Dominica Community High school followed by the Dominica Technical College. Upon completion of her A level's study, she then returned as a teacher to the Dominica Community High school where she taught for one year.

At the age of 19, in 1999 she made the bold decision of moving away from home and relocating to the country of Cuba where she pursued and completed a Bachelor's degree in Agricultural Engineering. During her six years study she met her now husband Clifford Martinez from the country of Belize.

Upon completion of her degree she once again made a very difficult decision and relocated to Belize. It is there that she became employed by the Belize Forest Department in 2006. Her primary role at the Forest Department consisted in managing the protected areas program, among though other task which were assigned as part of the mode of action of the FD.

It is during those year at the FD that she became acquainted with protected areas and forest management in Belize, even more so was her nurtured love for the people of Belize, and the wonderful country that she now calls home. It is also at the FD that she gained information on CATIE and the decision was made from 2008 that her further studies would be and were carried out in this institution.

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RESUMEN

Debido a la conciencia creciente del papel de los bosques como fuente de sustento a muchas comunidades dependientes, así como en la mitigación y adaptación del cambio climático, esta investigación se llevó a cabo con el objetivo de determinar las interacciones entre las causas directas y subyacentes de la degradación de bosques en el distrito de Toledo en Belice, análisis del manejo de suelo/bosque en Toledo, analizar el grado de degradación de los bosques degradados y sus relación con los factores geo- espaciales de caminos y los asentamientos y para determinar componentes importantes para el monitoreo de la degradación.. El estudio se llevó a cabo en el período de enero a agosto de 2012, en el distrito de Toledo de Belice, y una población cuyo principal sustento es generada por el uso de los bosques.

Para los objetivos de determinar las causas directas y subyacentes de la degradación, y el análisis del manejo de Suelo/bosque en Toledo, los datos primarios se recogieron mediante entrevistas semi-estructuradas y talleres. Los participantes formaron un grupo de 42 personas clave que representan el sector público, los actores locales y las personas y organizaciones involucradas en la promoción del uso sostenible de los recursos en Toledo. Para los objetivos de estudiar el alcance de la degradación de los bosques y el análisis de los efectos de los caminos / resolución sobre la degradación de los bosques y los bosques en regneracion, esta investigación hizo uso de los SIG (Sistema de Información Geográfica) y tecnologías de teledetección a través del cual un análisis de mezcla espectral (SMA) fue hecho en una serie de imágenes de satélite Landsat para el período de 1989 a 2010. Este análisis permitió la estimación de la proporción de los distintos componentes de cobertura del suelo (vegetación, suelo y sombra) dentro de un píxel y una validación adicional de verificación en el terreno con el uso de GPS. Para determinar los componentes importantes para el monitoreo de la degradación se realizó una revisión extensa de literatura ya existentes.

Los resultados del objetivo uno (1) se concluyó, que las causas de la degradación de los bosques y los bosques en estado degradados en el distrito de Toledo son: la agricultura utilizando el sistema de Milpa (57%), la tala legal e ilegal (38%) y el desarrollo de infraestructura (5%). Las causas subyacentes de la Milpa se consideran Pobreza (generación de ingresos) (44%), la tradición y la cultura (33%) y la educación (falta de sensibilización y creación de capacidad) (21%). Las causas subyacentes de la degradación de los bosques debido a la tala son la pobreza (generación de ingresos) (42%), las leyes débiles (Falta de aplicación y seguimiento) (35%) y la escasa capacidad institucional (23%). La extensión de bosque en regeneración a causa de Milpa se calcula en 6.086,97 ha y para la pérdida de

densidad debido a la tala de 62.028,09 hectáreas en el período 1989 a 2010. Un análisis de regresión con un nivel de significancia de 90% indican que existe un efecto negativo de la distancia a las carreteras y asentamientos de pueblos en bosques degradados la Milpa (P = 0,0009 y P0.0001 respectivamente). El análisis de regresión con un nivel de significancia del 90 % indicó que existe una relación lineal positiva de la distancia a los asentamientos degradación causada por la tala (p=0,001). No se observó un efecto de distancia a las carreteras y degradación causada por la tala (p = 0,5381).

La idea de que la degradación de los bosques es de la responsabilidad exclusiva del sector forestal puede ser colocado amablemente a descansa. Basado en los resultados del estudio, El bosque no sólo es utilizado por personas interesadas en la explotación forestal, pero es la fuente de productos maderables al igual que no maderables y de múltiples importantes eco sistémicos. Mayor conocimiento puede ser adquirido por el continuo monitoreo de la degradación y la implementación de recomendación para la mejora en el manejo, de la tierra / bosque en Toledo.

Palabras claves: degradación de bosque, bosques degradados, regeneración, Milpa, la tala, Toledo, Belice

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SUMMARY

Due to the growing awareness of the role of forest as a source of livelihoods to many forest dependent communities, as well as in Climate change mitigation and adaptation, this research was implemented with the objective of determining the interactions between the direct and underlying causes of Forest Degradation in the Toledo district of Belize, analysis of land/forest management in Toledo, analysis of the extent of degradation and its relation to the geo-spatial features of roads and settlements and to determine, important components for monitoring forest degradation. The study was carried out within the period, January to August, 2012, in the Toledo district of Belize, where the population main livelihood is generated from direct and indirect forest use.

For the objectives of determining the direct and underlying causes of forest degradation, and analyzing of forest management in Toledo, primary data were collected using semi-structured interviews and workshops. The respondents formed a group of 42 key persons representing the Government sector, local stakeholders and persons and organizations involved in promoting sustainable resource use in Toledo. For the objectives of studying the extent of forest degradation and its relationship to the geo-spatial features of roads/settlement, this research made use of GIS (Geographic Information System) and Remote sensing technologies through which a Spectral Mixture Analysis (SMA) was done on a series of Landsat Satellite Images for the period 1989 to 2010. This mixture analysis allowed for the estimation of the proportion of different land cover components (vegetation, soil and shadow) within a pixel and further validation by ground-truthing with the use of GPS. The determination of important components for monitoring degradation was done by literature review.

The results of objective one concluded; that the causes of forest degradation and regeneration of forest in the Toledo district are; Milpa farming (57%), Legal and illegal logging (38%) and infrastructure development (5%). The underlying causes of Milpa farming are considered Poverty (income generation) (44%), tradition and culture (33%) and education (lack of awareness and Capacity building) (21%). The underlying causes of forest degradation due to logging are poverty (income generation) (42%), weak laws (Lack of enforcement and monitoring) (35%) and poor institutional capacity (23%). The extent of forest in regeneration caused by Milpa farming is calculated at 6086.97 ha and for density loss due to logging at 62,028.09 ha for the period 1989 to 2010. An Exponential regression analysis (Non-Lineal) with a level of significance of 90% indicate that there exists a direct negative effect of distance to roads and settlements on regenerating forest caused by milpa farming (P =0.0009 and p=0.0001 respectively). A Lineal regression analysis with a level of significance of 90%

indicated that there exists a positive effective of distance to settlements on logging (P= 0.0001) No effect of distance to roads was observed for degradation caused by logging (p= 0.5381).

The misconception that forest degradation is solely generated from within the forest sector can be kindly placed to rest based on study results such as this. Forest is not only used for logging but is the source various timber and NTFP's important to the everyday livelihood of many forest dependent communities. Even greater knowledge can be gained by the continued monitoring of degradation and continued sustainable use by the implementations of recommendation for improving land/forest management in Toledo.

Key words: Forest degradation, degraded forest, regeneration, Milpa farming, logging, Toledo, Belize.

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LIST OF UNITS, ABBREVIATIONS AND ACRONYMS

BERDS	Biodiversity and Environmental Resource Data System of Belize
CATHALAC	Water Center for the Humid Tropics of Latin America and the Caribbean
CFM	Community Forest Management
CIFOR	Center for International Forestry Research
CO2	Carbon Dioxide
FAO	Food and Agricultural Organization of the United Nations
FD	Forest Department
GDP	Gross Domestic Product
GHG	Green House Gases
GIS	Geographic Information System
GOB	Government of Belize
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
GPS	Geographic Positioning System
GV	Green Vegetation
HA	Hectares
IFAD	the International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KM2	Kilometer Squared
LTFL	Long Term Forest License
m	Meters
MAF	Ministry of Agriculture and Fisheries
MOE	Ministry of Education
MOWT	Ministry of Works and Transport
NFTP'S	Non Timber Forest Products
NGO'S	Non-Governmental Organizations
NHDAC	National Human Development Advisory Committee
REDD+	Reduced Emission from Deforestation and Degradation
SATIIM	Sarstoon-Temash Institute for Indigenous Management
SHI	Sustainable Harvest International
SIB	Statistical Institute of Belize
SMA	Spectral Mixture Analysis
TIDE	Toledo Institute for Development and the Environment
THFI	Toledo Healthy Forests Initiative
TWB	the World Bank
UNEP/CBD	United Nation Environmental Program/Convention on Biological Diversity

WOE	Weights of Evidence
YCT	Yá axchè Conservation Trust

1 INTRODUCTION

1.1 Background

For hundreds of years the people of Toledo have lived dependent on their surrounding forest for the creation of livelihoods, cultural and spiritual practices, household material, game species, gathering of fruits and medicinal plant and for wellbeing attributed to the clean air, water and aesthetics of having forest as a day to day part of their culture.

However an increasing population and the need for cash have been resulting in unsustainable land-use practices which have caused deforestation, forest degradation, and even soil degradation. One would hope that Belize, proud of having more than 38% of its national territory under protected areas status, would be exempt from contributing to Climate change, this however is not the case, and like many other developing countries, forest degradation and deforestation contribute to the presence Co2 in the atmosphere which has been convicted as, the main catalyst in Climate Change.

By IPCC standards, climate change refers to, "any change or variation in the climate over time" (IPCC, 2001). This variation in climatic activities has been blamed on human activities which have resulted in an inflated amount of Greenhouse Gases in the atmosphere. In Belize, the main factor contributing to carbon emissions has been land use change, ,representing 69% of total GHG emissions , primarily from release of CO2 by burning vegetation during clearance and from the soil during cultivation. The energy sector is the second largest contributor with 21% (Fuller y Wilson 2002).

Two of the main human induced activities, that have contributed to Climate change, within the Land use and land use change category are deforestation and forest degradation(IPCC 2003a). Great emphasis has been placed on reducing the rapid rate of deforestation and forest degradation of tropical forest, due to the important role of tropical forest in mitigating and adapting to Climate change. (Kanninen *et al.* 2007). Just as important is the enhancement of degraded forest to allow for the return of forest productivity in supplying environmental goods and services through restoration and rehabilitation(CIFOR 2009; FAO 2011). This was especially highlighted one year after the Bali Action Plan was agreed and the main focused was shifted from just reducing deforestation and degradation but to conservation, sustainable management and enhancement of Carbon stocks.

Though this study's main focus is on the anthropogenic causes of degraded forest, Just as important though much more difficult to manage are the impacts of Natural disturbances (Hurricanes and Fires) on Tropical Forest. Hurricanes in Belize date back to 1785 based on Friesner 1993. The central coast of Belize has been subject to hurricane strikes throughout recorded history with immense human and material cost to the Belizean people (Mccloskey y

Keller 2009). Being situated within the hurricane belt of the tropics Belize is periodically subject to hurricanes and tropical storms, particularly during the period June to July (Friesner 1993).

Belize has been hit by six major hurricanes of category 3 or higher at landfall within the last 70 years. These are the unnamed hurricane of 1931 (Mccloskey y Keller 2009) unnamed because the earliest hurricanes were not fully reported or documented (Friesner 1993), hurricanes Janet (1955) and Keith (2000), which passed to the north of Belize City, Hattie (1961) and Greta (1978), which made landfall at Mullins River and just north of Dangriga, respectively, and Iris (2001). All of these hurricanes devastated coastal towns, except for Iris (2001), which made landfall in a relatively unpopulated area near Monkey River and devastated tropical forest (Mccloskey y Keller 2009). Hurricane Iris devastated an approximate 180,000 ha in 2001 and Hurricane Richard an approximate 300,000 ha in 2010 (Cho[1] 2011).

The Reduction of deforestation and forest degradation and enhancement of degraded forest is very hard to accomplish at the national level due to the great dependence of our communities on tropical forest. It is keeping in mind this dilemma, that many countries such as Belize have gained interest in not just the reduction of deforestation and degradation by enforcing the "do not touch policy" but by promoting sustainable forest management, reforestation and afforestation of forest, and other land-uses that encourage sustainable land management practices that are environmentally, economically and socially, appealing to all.

Belize can proudly boast, that unlike other developing countries, it has been stated as being a "net remover (sink) of GHGs from the atmosphere" and in 1994, tree growth in logged forests, plantations, and on cleared lands had absorbed approximately 6 million metric tons of CO2 per year, against a total emission of all GHGs estimated, at just less than 3 million metric tons (Fuller y Wilson 2002).

1.2 Defining forest degradation and degraded forest

The lack of a consented understanding of forest degradation can be made evident by the over 40 definitions that exist for the same. These definitions have ranged from ones focused on the ecological integrity of a forest, the productive importance, the ability to provide goods and services and especially the effects on carbon stocks. International conventions as well have varying definitions of forest degradation, which are chosen based on the main focus of these conventions.

- In the framework of REDD the IPCC, defines degradation as: "*A direct human-induced loss of forest values (particularly carbon), likely to be characterized by a reduction of*

[11] Cho, P. 2011. Hurricane Richard, 2010. (email). Researcher.

tree crown cover. Routine management from which crown cover will recover within the normal cycle of forest management operations is not included"(IPCC 2003a).

- Naburrs in 2007 defines degradation as: *Reduction in forest biomass through non sustainable harvest or land-use practices possibly resulting in substantial reductions of forest carbon stocks from selective logging, fire , collection of fire wood and other anthropogenic disturbance"* (Nabuurs *et al.* 2007).

- Based on the Verified Carbon Standard degradation is defined as: "*the persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuel wood extraction, timber removal or other such activities, but which does not result in the conversion of forest to non-forest land (which would be classified as deforestation), and qualifies as forests remaining as forests"*

Notwithstanding the various definitions that exist, this writer supports, that the definition for forest degradation used at the local level, while keeping in mind the conditions for reporting and monitoring under conventions, should always reflect the local context. By local context one refers to the management uses and objective of the area as well the traditions, social structures and environmental policies of the area in question.

Considering the national context of Belize and the high dependence on forest of most communities,(not necessarily for Carbon), forest degradation in Belize is considered "*Changes within the forests that negatively affect the structure or Function, and thereby lower the capacity to supply products and/or services*" (FAO 2007). By the use of this definition, it is believed that all the uses (though not specifically implied) of forest are important. Forest or areas that have lost their ability to provide the required products or services (based on the management objective of the areas) would thus be considered as degraded forest.

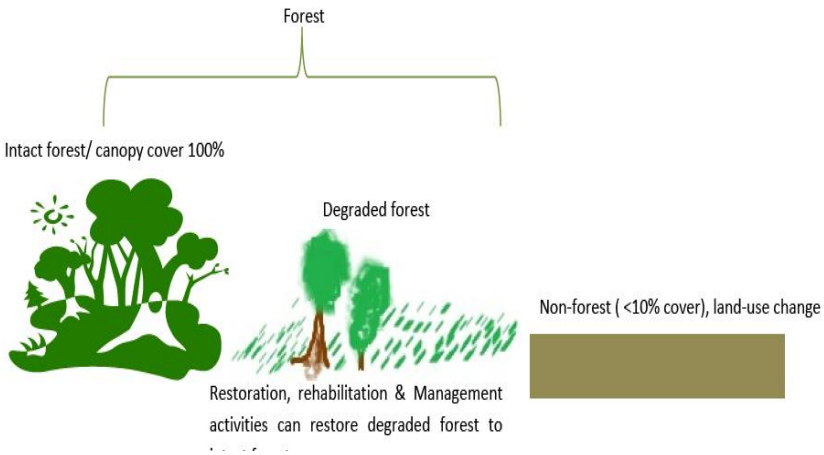

Figure 1. Degradation process

If one were to base on the FAO's definition of degraded forest, forest in degraded states are considered as having an altered forest structure, crown cover, species composition and stocking. This forest area may have a reduced capacity, when compared to the original forest, to provide goods and services and others

functions with limited or no productivity(Lund 2009). In other words degraded forest is neither here or there, but has the definite ability through rehabilitation, restoration and management to regain functions similar to the original forest it replaces *(Fig 1).*

Based on the above use of the terms, the forest of Toledo is comprised of a mosaic of, degraded forest, and agricultural uses, among others. This definition allows us to classify regenerating areas during the fallow period of Milpa Farming, as well as other areas with vegetation growth with the potential to retain full functionality in situ, as forest.

Forest degradation, and activities that result in the presence of degraded forest, approximately 2 million ha globally (FAO 2011), is the result of a complex mixture of varying direct and underlying causes (CIFOR 2000). The causes of degraded forest are almost impossible to understand without in-depth study and scientific technologies (CIFOR 2000; Kanninen *et al.* 2007).

Globally, direct causes of forest degradation have been linked to agricultural practices, illegal and legal logging, infrastructure development (e.g. roads) and fuel wood extraction (CIFOR 2000; Kanninen *et al.* 2007). Underlying causes, on the other hand, have been related to economic factors such as market growth and demand for a selected specie, institutional and policy factors, technological (e.g. production change related to the timber, and agricultural sector), sociopolitical/cultural factors which may include, but is not limited to public attitudes, values and beliefs and demographic factors (population growth)(Geist y Lambin 2002; Kanninen *et al.* 2007).

1.3 Importance of study

The need of maximizing the potential of tropical forest to mitigate and adapt to Climate change has placed enormous focus on understanding the complexity of factors that result in Forest degradation. This has also allowed us to place greater emphasis on understanding and respecting the needs, of forest dependent communities. Though the vision is clear, it cannot be achieved without finding a balance between climate change mitigation and adaptation activities and providing continued use of its resources, by dependent communities.

With greater understanding of degradation, it is hoped that decisions will be focused on establishing policies and institutions with the capacities, to promote sustainable production practices and sustainable use of forest resources which compliment mitigation and adaptation activities, under the climate change mitigation and adaptation agendas, both nationally and globally.

2 GENERAL OBJECTIVE;

Determination of the direct and underlying causes of forest degradation, and the extent of their consequences on forest in the Toledo district of Belize

3 SPECIFIC OBJECTIVES;

- Determine the direct and underlying causes of Forest Degradation in Toledo.
- Determine activities for improved land management in the Toledo district
- Determine the extent of forest degradation in the Toledo district and the possible link to the geospatial features of roads and settlement
- Determine important components for monitoring forest degradation

4 STUDY QUESTIONS AND HYPOTHESIS;

Table 1; Study question and hypothesis

Specific Objectives	**Study questions**
Determine the direct and underlying causes of Forest Degradation in Toledo.	What are the direct anthropogenic causes of Forest Degradation in the Toledo District?
	What are the underlying causes of these direct anthropogenic activities which facilitate forest degradation in the Toledo district?
Detemine the extent of Forest Degradation in the Toledo district.	what is the extent of forest degradation caused by human activities in the Toledo district of Belize?
	Does there exist a relationship between degradation and the geospatial features of roads and settlement?
Determine important components for monitoring forest degradation that are applicable in Belize	What are the components of good monitoring systems? Can existing monitoring methods of Degradation be adapted to the context of the Toledo District? Does the local population play a role in monitoring forest degradation and restoration?
Determine recommended activities for improved land management in the Toledo district	What are the weakness of land management in Toledo?
	what are the strengths of land management in Toledo?
	what what are the recommendations for improving land management?

5 JUSTIFICATION

Forest degradation is a very complex process, which may result from the interaction of various direct and underlying causes. Just as important is that many conditions and factors may act as

enablers to this process. The answers too many of these questions surrounding forest degradation are unknown, and the use of scientific studies and technologies will definitely lend a hand in understanding this phenomena. Greater understanding will ultimately lead to better management decision, and policies benefiting to all.

6 SYNTHESIS OF RELEVANT RESULTS AND CONCLUSIONS OBTAINED IN STUDY

6.1.1 *Direct and underlying causes of forest degradation and degraded forest in Toledo*

Based on results obtained in this study, the main cause of forest degradation and degraded forest in the Toledo district are slash-and-burn agriculture (Milpa), and logging.

The main agricultural practice in the Toledo district is Milpa Farming. Milpa (meaning 'corn field' in the Aztec language) is a traditional type of slash-and-burn agriculture in which the soil is left in fallow (for 10-12 years) after each crop. This farming system encompasses a wide range of factors, rules, social relationships, and production relationships within a community in which the main activity is agriculture(Levasseur y Olivier 2000; Binford 2007).The Mopan and Q'eqchi' Maya of Toledo , traditionally employ swidden agriculture as their primary means of subsistence. Corn, beans, and rice are the main staples. (Binford 2007).

The people of Toledo have also used the forest for timber extraction for hundreds or years without causing great depletion of timber resources. Within the last 30 years however, Illegal Logging or the illicit felling of trees in Toledo, done by villagers and outsiders who usually work for illegal traders, legal traders, and local influential leaders have increased tremendously.

The high demand of Rosewood (*Dalbergia stevensonii*) in the Asian market has resulted in many farmers changing their livelihoods, by abandoning their farms and directing efforts to the extraction of timber species for fast cash needed to pay school fees and medical fees which cannot be met by regular subsistence farming.

Except for three long term forest licenses issued for logging under sustainable management guidelines and three community forest management plans, most other legal logging activities are carried out under one year licenses and petty permits. These permits though legal, as explicitly stated within, are not for sustained yield. This implies that no sustainable plans or guidelines are required for exploitation of timber products under these licenses. This permit allows for the extraction of timber not exceeding the amount of $50Bze ($25us).

6.1.2 Underlying causes of degraded forest caused by Milpa farming

Based on the responses the complexity of forest degradation in the Toledo district can be explained by the interplay of factors such as; Poverty, lack of formal and informal education and the cultural and traditional practice. It is believed that most people who practice Milpa farming (Particularly in rural communities), by all accounts, are considered poor without alternative income sources. this factor dose not however work alone, but is accompanied by the lack of formal and informal education, especially informal education gained through public awareness and capacity building on sustainable land management practices. The factors of poverty and education when interplayed with cultural practices and traditional ways of life have lent fuel to the cause of Milpa farming as a direct factor in forest in regeneration in the Toledo district.

6.1.3 Underlying causes of forest density loss caused by logging

The dynamics of logging which has resulted in density loss is brought about by underlying factors almost distinct to Milpa farming. This activity is considered to be driven by poverty, poor institutional capacity and weak laws. The respondent consider that logging as Milpa farming stems from poverty which is fueled by the lack of alternative livelihood and income generating sources which has resulted in the harvesting of timber products as a means of generating cash, which is used to purchase household item and to pay for varying fees from time to time. Poverty however is not only to blame as not only the poor in Toledo carry out logging activities. Weak laws and the monitoring and enforcement of the same are considered by 35% of the persons interviewed as contributing to unsustainable logging activities. Lastly but not least in importance is poor institutional capacity and structures, which has resulted in persons within the forest sector of Toledo, with limited capacity, and institutions lacking in programs geared at promoting sustainable forest use.

6.1.4 Extent of forest Degradation and possible link to roads and settlements

Based on an SMA (Spectral Mixture Analysis) of Landsat images, the extent of forest in regeneration in fallow, caused by Milpa Farming, were detected within areas classified as Agricultural uses, shrub-land and urban areas in the 2011 Ecosystems Map of Belize(Appendix 1) (BERDS 2012). These areas from 1989-2010 experienced a total increase of vegetation cover of 6086.97 ha. The same analysis done using, areas classified as forest in the Cherrington 2010 study on deforestation in Belize, confirmed loss in vegetation density caused by logging from 1989 – 2010, of 62,028.09 ha.

The results of the analysis of the relationship of roads and settlement and degradation caused by logging and Milpa farming revealed; that statistically there exist no effect of distance to roads on forest density loss caused by logging (P=0.5381). There is however an effect of settlements (P=0.0001).Forest degradation caused by logging increases with increased distance away from settlements in Toledo (also evident in the WOE analysis).

The extent of forest in regeneration caused by Milpa farming, from a visual perspective, are very closely linked to both the presence of road and settlement, with a high concentration of regeneration along the network of roads and settlements in Toledo. This was supported by the lineal regression analysis with a level of significance of 90% which indicates that there exists an effect of distance to roads and distance to settlements on regenerating areas caused by Milpa farming. This is evident in the WOE analysis where there is a reduction of regeneration with increased distance away from roads settlements (P =0.0009 and P=0.0001 respectively).

6.1.5 Recommendations

Recommendations for improving land management and sustainable practices in Toledo were based on an analysis of land management in Toledo district (Fig 4), and literature review on sustainable practices both for the agricultural and forest sector. These recommendations also took into account sustainable practices already existent in Toledo and Belize, though in a lesser proportion but can be replicated by others in Toledo.

Main results from the analysis of land management are geared at;

- Great educational awareness
- Better monitoring and enforcement
- Creation of partnerships and involvement of local stakeholders

Based on literature review and existing practices, the recommendation for promoting more sustainable practices are;

- promote sustainability of timber extraction in Toledo, there is a need for better monitoring of activities carried out under licenses and greater enforcement
- capacity building on sustainable forest management
- awareness centered on community forest management,
- considering that land availability may decrease in Toledo, the promotion of Agroforestry systems, already practiced by intercropping using cocoa and other valuable timber species may very well be a solutions to increasing land productivity.
- Increased fallow period to increase soil productivity. The number of years that the soil is under cultivation may be offset by longer fallow periods.
- Increasing the practice of slash and mulch (practiced in Toledo) as is a key way of increasing soil productivity.

6.1.6 Conclusion

Forest degradation in Toledo district is the cause of a very complex interplay of different direct and underlying causes as determined by this study. The rehabilitation and enhancement of forest in regeneration is dependent on the collaboration of multiple stakeholders and also the ability and willingness of the government of invest valuable resources into continued monitoring of the causes and the extent.

What can definably be seen as a positive outcome of this study is the identification of measures and ways of moving forward, agreed upon by the relevant sectors involved in land management and decision making in the Toledo district. This understanding of what should be done in Toledo though not openly stated amongst the different stakeholders is important for the facilitation of dialogue, when such a step is taken.

Land management and practices geared at enhancing regenerating areas does not have to start from zero, and should make use of existing structures, technologies and experiences both in Belize and abroad that can be used as guides in promoting and implementing, sustainable land uses in the Toledo district.

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8 ARTICLE ONE (1). DIRECT AND UNDERLYING CAUSES OF FOREST DEGRADATION IN THE TOLEDO DISTRICT

SUMMARY

Due to the growing awareness of the role of forest as a source of livelihoods too many forest dependent communities, and as the leading option to mitigating and adapting to climate change, this research was implemented with the objective of determining the interactions between the direct and underlying causes of Forest Degradation, and to analyze forest management in the Toledo District of Belize. The study was carried out within the period, January to August, 2012, in the Toledo District of Belize. Toledo is the southern mort district of Belize with over 50 villages, and a population whose main livelihood is generated from subsistence farming.

For the objectives of this study, primary data was collected using semi-structured interviews and workshops with a group of 42 key informants. This group consisted of persons from the Government sector, local stakeholders and persons and organizations involved in promoting sustainable resource in Toledo. The results of objective one concluded; that the causes of forest degradation and degraded forest in the Toledo district are; Milpa farming (57%), Legal and illegal logging (38%) and infrastructure development (5%). The underlying causes of Milpa farming are considered Poverty (income generation) (44%), tradition and culture (33%) and education (lack of awareness and Capacity building) (21%). The underlying causes of forest degradation due to logging are poverty (income generation) (42%), weak laws (Lack of enforcement and monitoring) (35%) and poor institutional capacity (23%).

In accessing land management in Toledo with emphasis on forest use, recommendation for reducing forest degradation were based on recognition of the current strengths and weakness of management. Most highly recommended for reducing degradation is the raising of public awareness of sustainable land use, the creation of partnerships, involvement of local communities in land management and better implement of monitoring and enforcement activities.

Notwithstanding activities or next steps that can be enforced for reducing degradation, with the aim of promoting sustainability or land uses that exist based on literature it is recommended that Milpa farming can be done more sustainably, by the lengthening of fallow period , intensification of agricultural areas and even the establishment of agroforestry systems. Logging can be enhanced by promoting sustainable forest management guidelines and activities and increased monitoring and enforcement of the forest act of Belize. Reduction of forest degradation by greater sustainability of land uses will only become a reality based on recognition of all stakeholders that the forest is beneficiary to all, both for production and in mitigating and adapting to climate change.

1.4 INTRODUCTION

8.1.1 Problem statement

Since the 1700's, the concentration of $C0_2$ has increased due to two major human impacts:1) emissions from fossil fuel combustion and industrial processes and 2)land use and land use change (IPCC, 2007). Scientists estimate that deforestation and forest degradation account for around 20% of the annual greenhouse gas emissions that fuel climate change. This is more than the emissions from the entire global transport sector (Cifor 2009).As such maintaining existing forests has been promoted as one of the least expensive and integral climate change mitigation options (Kanninen *et al.* 2007; Kaimowitz 2008). The enhancement of forest is also vital as this allows for the return of forest productivity in supplying environmental goods and services through restoration and rehabilitation(CIFOR 2009; FAO 2011). This was especially highlighted one year after the Bali Action Plan was agreed and the main focused was shifted from just reducing deforestation and degradation but to conservation, sustainable management and enhancement of Carbon stocks.

Just as important, though sometimes forgotten, when compared to the charismatic appeal of Climate change is that Forests are integral to the lives of the people who live in and around them and to society as a whole. Forest are reported as providing livelihood to more than 1.6 billion worldwide and attributes US$270 billion worth globally of forest products traded internationally, with developing countries accounting for more than 20 percent (TWB 2009).

The multiple uses of the forest which includes the production of both forest ecosystem goods such as timber, non-timber forest products (NTFPs) and services such as climate regulation, biodiversity conservation and watershed management are a reason for promoting holistic land-use management so as to promote sustainable development constantly keeping in mind, the ecological, technical, socio-cultural, economic and political-institutional dimensions of forest management.

8.1.2 Defining Forest Degradation

Before reaching a common definition for "forest degradation and "degraded forest", there must first exist a common understanding on just what is considered a 'forest'. Once agreement on what constitutes forest is established, then can we go about addressing degradation (Lund 2009). For the purpose of this study and the national definition adopted by the country of Belize, forest are considered *"Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ* (FAO 2007).

The lack of a consented understanding of forest degradation can be made evident by the over 40 definitions that exist for the same. These definitions have ranged from ones focused on the ecological integrity of a forest, the productive importance, the ability to provide goods and services and especially the effects on carbon stocks(Lund 2009; FAO 2011). International conventions as well, have varying definitions of forest degradation, which are chosen based on the main focus of these conventions.

IPCC defines degradation as: "*A direct human-induced loss of forest values (particularly carbon), likely to be characterized by a reduction of tree crown cover. Routine management from which crown cover will recover within the normal cycle of forest management operations is not included*"(IPCC 2003a).

- Naburrs in 2007 defines degradation as: *Reduction in forest biomass through non sustainable harvest or land-use practices possibly resulting in substantial reductions of forest carbon stocks from selective logging, fire , collection of fire wood and other anthropogenic disturbance"* (Nabuurs *et al.* 2007).

- Based on the Verified Carbon Standard, degradation is defined as: "*the persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuel wood extraction, timber removal or other such activities, but which does not result in the conversion of forest to non-forest land (which would be classified as deforestation), and qualifies as forests remaining as forests"*

This writer firmly believes that, the definition for forest degradation used at the local level, while keeping in mind the conditions for reporting and monitoring under conventions, should always reflect the local context. By local context one refers to the management uses and objective of the area as well the traditions, social structures and environmental policies, of the area in question.

Considering the high dependence on forest, of most communities in the Toledo district (not necessarily for Carbon), forest degradation in Belize is considered "*Changes within the forests that negatively affect the structure or Function, and thereby lower the capacity to supply products and/or services*" (FAO 2007). Based on interviews respondents consider that there is a high level of dependence of local on the forest for goods and services such as; food, medicinal plants, timber, land for agricultural cultivation, clean water supply, game species, and the general aesthetics which many stated has contributed to the wellbeing of persons leaving in Toledo.

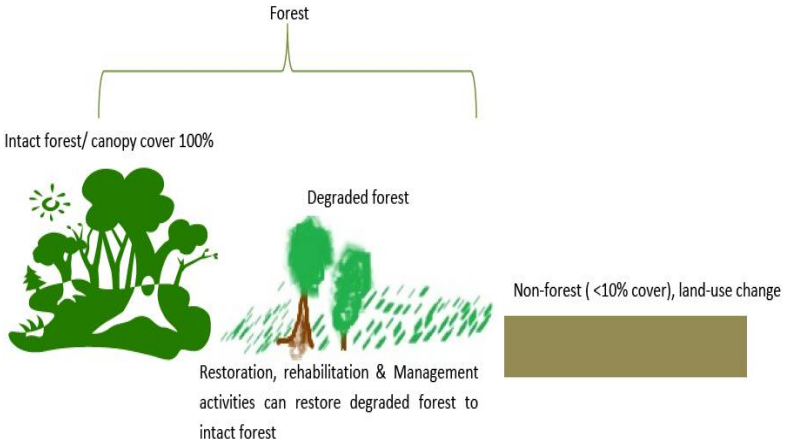

Figure 2. Degradation process

It is believed that this definition encompasses the main importance of forest, and the loss of the value of a good or service is not limited to a sector or group. Forest or areas that have lost their ability, to provide the desired or appreciated good or service, based on the management objective of the areas would thus be considered as degraded forest.

If one were to base on the FAO's definition of degraded forest, forest in degraded states are considered as having an altered forest structure, crown cover, species composition and stocking. This forest area may have a reduced capacity, when compared to the original forest, to provide goods and services and others functions with limited or no productivity(Lund 2009). In other words degraded forest is neither here or there, as one would state, but there is definite prospects for rehabilitation, restoration and based on management, ability of degraded forest, to regain the function of the original forest in situ (Fig 5). Degraded forests consist of vegetation cover surpassing 10%, lacking in structure and composition representative of the original forest.

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Based on the above use of the terms, the forest of Toledo is comprised of a mosaic of, degraded forest and agricultural uses among others. This definition allows us to classify forest during the fallow period of Milpa Farming, as well as other areas with vegetation growth with the potential to retain full functionality *in situ,* as forest.

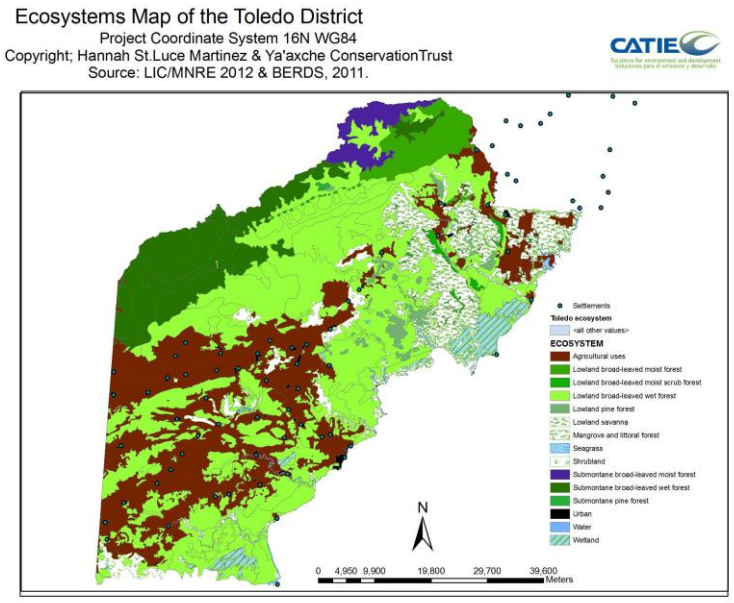
Forest degradation, and activities that result in the presence of regenerating forest, within most landscapes is the result of a complex mixture of varying direct and underlying causes (CIFOR 2000). The causes of degraded forest are almost impossible to understand without in-depth study and scientific technologies to help (CIFOR 2000; Kanninen *et al.* 2007).

Globally, direct causes of forest degradation have been linked to agricultural practices, illegal and legal logging, infrastructure development (e.g. roads) and fuel wood extraction (CIFOR 2000; Kanninen *et al.* 2007) and natural disturbances. Underlying causes, on the other hand, have been related to economic factors such as market growth and demand for a selected specie, institutional and policy factors, technological (e.g. production change related to the timber, and agricultural sector), sociopolitical/cultural factors which may include, but is not

limited to public attitudes, values and beliefs and demographic factors (population growth)(Geist y Lambin 2002; Kanninen *et al.* 2007).

8.1.3 Land-use in the Toledo district

The predominant Land uses in the Toledo district are; agriculture, (both mechanized and Milpa farming), urban areas, and a mixture of varying vegetation cover dominated by broad-leaf forest. Most villages are found within the agricultural areas of the district, below the foot hills of the Maya mountain block of protected areas. (Fig. 5)



Apart from the dominant land uses the forest of Toledo is also the source of a vast variety of timber and none Timber Forest Products (NTFP) utilized by the people for home construction, medicinal purposes, arts and crafts, firewood, ornamental to name a few.

Table 2: Percentage distribution of employment, by industry and district, 2009.

Industry	Belize District	Cayo	Corozal	Orange Walk	Stann Creek	Toledo
Agriculture	1.8	17.8	32.2	24.9	25.6	46.1
Construction	8.5	7.2	6.9	11.8	5.4	8.6
Retail	22.4	15.8	22.7	22.2	14.5	6.5
Tourism – Hotels, Restaurants etc.	13.4	10.6	6.3	6.4	14.0	8.6
Government	10.3	14.8	4.5	4.9	10.3	9.8
Personal Services	19.3	18.4	12.5	11.3	17.4	10.2
All other sectors	24.3	15.4	14.9	18.5	12.8	10.2
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

(NHDAC 2010)

approximately half of Belize's total population employed in agriculture can be found in the Toledo district (Table 2) (NHDAC 2010),

8.1.4 Milpa farming

The main agricultural practice in the Toledo district is Milpa Farming. Milpa (meaning 'corn field' in the Aztec language) is a traditional type of slash-and-burn agriculture in which the soil is left in fallow (for 10-12 years) after each crop. This farming system encompasses a wide range of factors, rules, social relationships, and production relationships within a community in which the main activity is agriculture(Levasseur y Olivier 2000; Binford 2007).The Mopan and Q'eqchi' Maya of Toledo , traditionally employ swidden agriculture as their primary means of subsistence. Corn, beans, and rice are the main staples. (Binford 2007).

Based on the Milpa system a plot will be used until the farmer detects a decrease in productivity and this area left to regrow through natural vegetation for several years with the hope of regaining soil nutrients for subsequent cultivation. This regrowth period is called "*fallow period* "which traditionally lasts between 10 and 12 years, allowing for soil fertility replacement.

Traditionally farmers within a village possess several plots (approximate 1-2 ac in size) which are rotated with one active plot and several plots in fallow within a given time frame. This however has changed in the last decades, due to population increase and shortage of lands prompting the use of land successively, without allowing for the fallow period, or with a much shorter fallow period when compared to the past.

Traditionally corn was planted once a year, in the month of May, which due to the rich nutrient content of soils, translated into a high production providing corn which lasted until the following year. This also has changed (according to the locals), with decreased yield in the last decades resulting in a corn harvest insufficient to last for a year.

In the modern context corn is cultivated twice a year, in May (*slash and burn*, known as *Milpa*, which uses fire to clear the vegetation) and in November (known as *Mata-hambre*, in Spanish literally "Hunger kills") without the use of fire, known as "*slash and mulch*"(Tut 2012).

Generally, *slash and burn* is applied to a full grown forest, either old growth forests or long fallow period forests, whereas *slash and mulch* is applied to relatively young growing vegetation. Both *slash and burn* and *slash and mulch* can be applied to the same plot in an alternate way throughout the years.

The combination of both techniques, *slash and mulch* and *slash and bu*rn, its rotary nature and the variable *fallow period* scenario have generated a very complex agricultural matrix in a mainly forest dominated landscape. One year old abandoned patches are normally grass dominated, while 2 to 3 year old abandoned parcels are rich in shrubs and small tree between 2 and 4 meters high. 5 to 10 year old fallow patches, are characterized by dense tree cover of thin trees that can reach 10m in height for fast growing species. One can also observe patches of 15 to 20m high

trees, in areas where conditions are presumably not adequate for agriculture production, due to the slope gradient or the presence of rocks (Ruscalleda 2012).

Based on Levasseur 2000 the farming system in the San Jose Village of Toledo which follows the modern agricultural slash and burn practice, was reported as contributing to the problem of forest degradation by fragmentation (Levasseur y Olivier 2000). Milpa farming has also resulted (in the fallow period) in the presence of regenerating areas (lacking in parameters that constitutes a forest, based on the 2006 FAO definition of Forest).

By law Milpa farming falls under the mandate of the former Ministry of Agriculture and Fisheries, and from 2012 the Ministry of Natural Resources and Agriculture. The main mandate of this department is to "transfer environmentally friendly technologies that will make farming more sustainable and farmers more competitive". The Ministry of agriculture has four operational programs namely; Livestock Development, Crop Development, Fruit Tree and Marketing, Agro-processing and Extension Services(MAF 2003).

The establishment of new plots for Milpa farming is first approved at the local government level with approval obtained by the Alcalde of the village. Milpa farms as all other farms in Belize are then registered at the ministry of agriculture.

Under the Agricultural Fires Act, chapter 204, revised edition 2000, slash and burn activities should be logged by local agricultural stations on an annual basis. This is advised in writing or in person to the agricultural officer for a license to do so, stating the location and extent of the area to be burnt and the reasons for burning.

8.1.5 Logging

Logwood (*Haematoxylon campechianum L.*), the source of dye used by the early Europeans textile industry, was the first important product extracted from Belize (Weaver *et al.* 1997). The economy of Belize, formerly the British colony of British Honduras, historically has been based on the extraction of mahogany (*Swietenia macrophylla King*). Mahogany formed the core of Belize's export economy from the late 1700s, when it surpassed logwood in export value, to the mid-1900s, when it declined relative to the growing sugar, citrus, and banana industries. Global demand for the precious wood has been the important driving force for mahogany logging in Belize.(Camille 1996).

In the early 1920s, the beginnings of systematic forest management in Belize brought to an end the unchecked forest exploitation that had been characteristic of the logging industry since the early 1700s.The Forest Department created in 1922 has been responsible for the transition of forestry from an economic activity based on all-out exploitation, with no concern for future resources, to one of intensive utilization and conservation. The Forest Department is responsible for controlling felling and promoting forestry practices on freehold lands, managing non-reserved

forested Crown land, and managing lands declared as forest reserve. The early work of the Forest Department on these reserves included regulating timber cutting and initiating forest regeneration programs (Camille 1996; Santos 2009; Sabido 2012)

By law the forest department of Belize has the legal mandate to issue five levels of permits under the Forest Act Chapter 213 of the Substantive Laws of Belize Revised Edition 2000. These are:

- Long Term Forest Licenses (40 years): for sustainable forest management under concession agreements which is accompanied by the development of a sustainable forest management plan.
- One year forest Licenses (1 year): not on a sustained yield basis for the working of timber or other Forest produce. Licenses for up to one year are issued by the FD, based on the capacity of the forest to supply the timber
- Salvage permits: for salvaging of forest products post affectation by hurricanes or natural disasters, No sustainable forest management plan required. the royalty value of the produce does not exceed one thousand dollars
- Petty permits: for the removal of few trees for the purpose of sale or domestic use. No sustainable forest management plan required the produce does not exceed fifty dollars;
- chicle license."

1.5 **JUSTIFICATION**

The ever growing demand for forest resources especially for timber and food supply has resulted in forest degradation, prompting the need for sustainable management and at the national and local level (Davidar *et al.* 2010).

Forest degradation, is the result of a complex mixture of varying direct and underlying causes (CIFOR 2000), and the causes of degraded forest are almost impossible to understand without the use of in-depth study and scientific technologies (CIFOR 2000; Kanninen *et al.* 2007). This will allow for better management, by allowing prioritization and allocation of scarce human and financial resources in reducing degradation and the restoration and rehabilitation of degraded landscapes (FAO 2011).

1.6 **MATERIAL AND METHODS;**

The Toledo District is one of six districts found in the country of Belize. Belize is located between 15°52' and 18°30' North Latitude and 87°28' and 89°14' West longitude. It is the second smallest country in Central America, measuring 280 km from north to south and 110 km from east to west with a land area of 22, 963 km2. Topographically, the country is divided into two physiographic regions: the northern lowlands and the Maya Mountains. The southern plains and

Maya Mountains are dominated by submontane and montane broad leaf forest interspersed with pine (Pinus caribaea var. hondurensis) savannas (Young 2008).

The Toledo District is the southernmost district in Belize with a total area of 4,650 km². The district's capital is the town of Punta Gorda. According to the 2010 census, Toledo District has a population of 30,538 persons with at least five distinct cultures contributing to its rich cultural heritage. These groups include the Mopan and Kekchi Maya, Garifuna, Kriol, East Indians, and Chinese (SIB 2010). Land in the Toledo District, except for a few private plots and communal lands is owned by the state (Levasseur y Olivier 2000) with nine (9) protected areas of National Park, Forest Reserves, Nature Reserves and Marine Reserve categories.

The Toledo district is composed of flat coastal plains, gently rolling foothills and undulating lowlands, the relatively high Maya Mountains reaches to about 1 000 meters in elevation. The uplands are classified as wet sub-tropical, with annual precipitation of 3 000 to 4 500 mm, while the lowlands, with a yearly rainfall of 2 000 to 3 500 mm, have a wet tropical climate. Severe storms, which sometimes significantly damage crops, occur in the wetter season (June to November) (IFAD 2007).

Like many other Mayan communities in Central America, the Mayan community in Belize continues to rely upon forested areas as integral components of their agricultural systems (Diemont *et al.* 2011). Mopan Maya also utilize primary forest, known as old nuk che, for selective timber cuts, hunting, and gathering of food, medicines, and firewood (Diemont *et al.* 2011). The Toledo District is one of the most densely forested regions of the country, and most of these communities lie within or adjacent to forests and declared protected areas (Santos 2009).
The population growth from 2000 to 2010 is reported as 30% amounting to 7289 persons within the last 10 years (SIB 2010).

Methodology

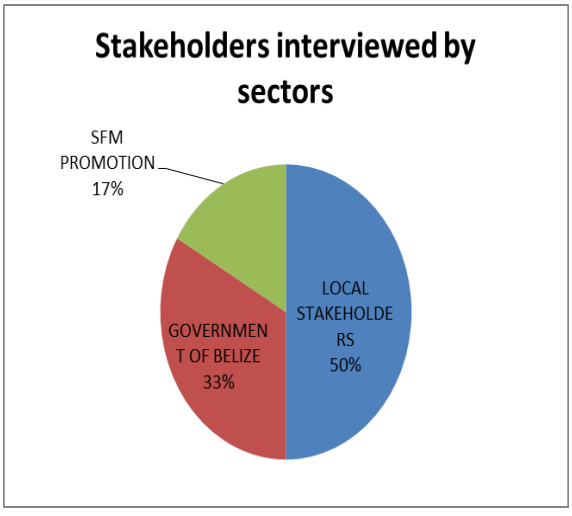


Figure 3. Stakeholders interviewed by sector

The primary method of this research was collection of qualitative data in the field, mainly through semi-structured interviews to 42 key informants. The key informants were selected after realizing a stakeholder's analysis of the main stakeholders of the forest of Toledo. This analysis consisted in recognizing the person who stands to be affected most by a study such as this or persons considered integral in land-use management in the Toledo district. This group of 42 was finally broken down into three main group representing persons from the government of Belize, local

stakeholders (residents of Toledo) and organizations and experts involved in the promotion of sustainable forest management in the Toledo district (Figure 6)

The interview instrument consisted of 35 questions designed to elicit information on 1) general information of the informant 2), information on the local and commercial uses of the forest in Toledo, 3), directed causes of Forest Degradation 4), underlying causes of forest degradation 4), and questions geared at gathering information on what is believed to be the strengths and weaknesses of forest management in Toledo and 5), a section on recommendations for better forest management in Toledo (Appendix 2 &3). Section 4 and 5 were considered important, since they allowed the writer to recommend on ways of reducing forest degradation, based on the respondents, on what is considered as lacking and necessary for reducing forest degradation.

Most interviews were recorded using a Kodak digital recorder, to allow for easier processing of data. These recorded responses were immediately transcribed following each day's round of interviews into an excel database. In most cases, informants were fluent in English, but in several cases some help from a local translator was obtained.

During the course of this research three (3) workshops were implemented one at the local level and two at the governmental level. The main purpose of these workshops was to familiarize key informants of this research and to gain confidence with the key informants.

Secondary sources were used to supplement the data collected during the interviews; these included data from census at the district and village level, records and database from the Forest and Land Information Center of the Government of Belize, published articles, and recent reports from various Ministries of government.

Data Analysis

Interview responses were recorded and then transcribed into a spreadsheet using Microsoft Office Excel 2003-2007 (Microsoft Corporation 2003). The collected data was then analyzed using a descriptive analysis in InFostat 9.

Table 3 results of contingent table analysis

Variable	Chi squared	P value
Milpa Farming	3.41	0.1818
Logging	5.54	0.2361
Infrastructure	2.88	0.2366

For the purpose of analyzing association between the sectors and the responses a contingency table was used in InFoStat. Contingency tables are well established statistical methods for analyzing relationships, suitable for categorical variables. The results of this analysis essentially allowed display, of the relationship between

responses and sector. With a level of significance of 90% there was no association observed between sector and responses. This analysis can be used to conclude that there existed no bias of response based on sector.

Constraints

The number of key informants was limited by language, resource and time constraints, as well as by limited communication between the researcher and local stakeholders. The unexpected general political elections in the month of March of 2012 also slowed down research activities tremendously.

1.7 RESULTS;

8.1.6 Direct causes of forest degradation in the Toledo district

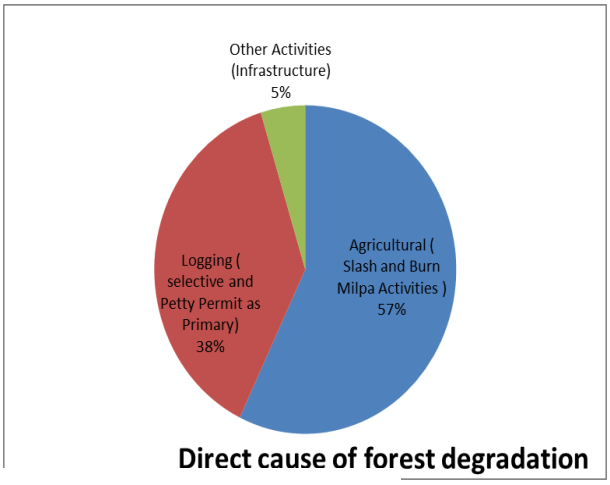


Figure 4. Direct causes of Forest degradation

Results showed that more than 50% of the persons interviewed consider Milpa farming to be the principal direct cause of forest degradation. the second most impacting cause logging (illegal and legal) and a small percentage who considered infrastructure development as the main direct cause of forest degradation (Fig 7)

Contrary to other studies, fuel wood extraction, was not highlighted as a main cause of degradation. Though this activity may contribute to an unknown percentage of degradation, person's interview stated that there is a growing change of energy source from fire wood to Butane gas. Fuel wood extraction may also be less damaging considering that local respondents did state that many persons within villages are inclined to the use of debris and material on land post slash and burn for fire wood rather than extraction from forested areas.

8.1.7 Underlying causes of Forest Degradation caused by Milpa Farming.

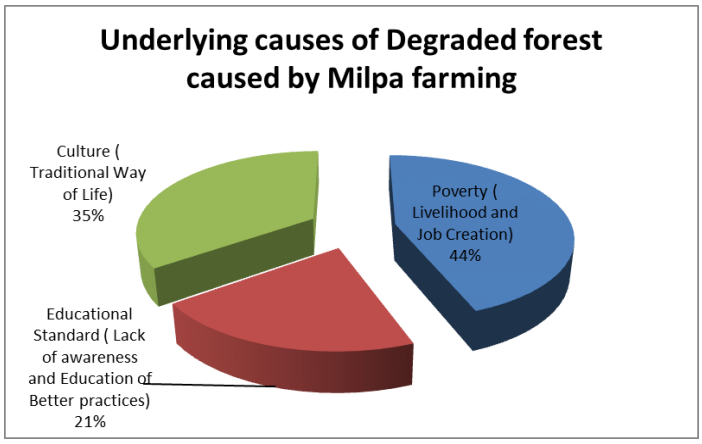


Figure 5. Underlying causes of Milpa Farming

Based on the responses the complexity of forest degradation in the Toledo district caused by Milpa farming, can be explained by the interplay of factors such as; poverty, lack of formal and informal education and cultural and traditional practice. People are classified as poor due to the lack of alternative income sources. This rings true, especially for persons who reside in rural communities. this factor does not however work alone, but is accompanied by the lack of formal and informal education, especially informal education gained through public awareness and capacity building on sustainable land management practices. The factors of poverty and education when interplayed with cultural practices and traditional ways of life have lent fuel to the agent of Milpa farming as a direct cause of forest in a state of regeneration in the Toledo district (Fig 8).

8.1.8 Underlying causes of Forest Degradation caused by Logging.

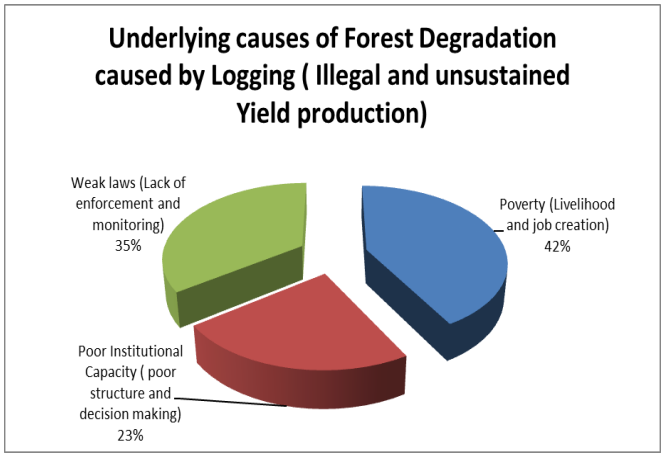


Figure 6. Underlying causes of logging in Toledo

The factors relating to logging which has resulted in density loss is brought about by underlying factors almost distinct to Milpa farming. This activity is considered to be driven by poverty, poor institutional capacity and weak laws. The respondent consider that logging as Milpa farming stems from poverty which is fueled by the lack of alternative livelihood and income generating sources which has resulted in the harvesting of timber products as means of generating cash, which is used to purchase household item and to pay for varying fees from time to time.

Poverty however is not only to blame as not only the poor in Toledo carry out logging activities. Weak laws and the monitoring and enforcement of the same are considered by 35% of the persons interviewed as contributing to unsustainable logging activities. Lastly but not least in importance is poor institutional capacity and structures, which has resulted in persons within the

forest sector of Toledo, with limited capacity and institutions with programs lacking in the promotion of sustainable forest use(Fig 9).

1.8 DISCUSSION

8.1.9 Milpa farming as the main cause of Forest degradation.

Based on the results of this study, Milpa farming is considered to be the main direct cause of forest degradation in the Toledo district of Belize. This finding is supported by various other studies and scientific documents (e.g. Levasseur y Olivier 2000) which explored the impacts of farming systems on a forest landscape particularly during the slash and burn stage. Its main impacts are related to fragmentation of intact forest and the presence of regeneration within the agricultural areas of the Toledo district.

Generally, *slash and burn* is applied to a full grown forest, either old growth forests or long fallow period forests, whereas *slash and mulch* is applied to relatively young growing vegetation. Both *slash and burn* and *slash and mulch* can be applied to the same plot in an alternate way throughout the years.

The combination of both techniques, *slash and mulch* and *slash and bu*rn, its rotary nature and the variable *fallow period* scenario have generated a very complex agricultural matrix in a mainly forest dominated landscape. One year old abandoned patches are normally grass dominated, while 2 to 3 year old abandoned parcels are rich in shrubs and small tree between 2 and 4 meters high. 5 to 10 year old fallow patches, are characterized by dense tree cover of thin trees that can reach 10m in height for fast growing species. One can also observe patches of 15 to 20m high trees, in areas where conditions are presumably not adequate for agriculture production, due to the slope gradient or the presence of rocks(Ruscalleda 2012).

8.1.10.Recommendation

Management focus should not be limited to the process and causes of degradation but also on the important role of regenerating areas in the grand scheme of things. The roles of secondary forest and areas in regeneration have been highlighted by the REDD+ agenda, as an opportunity to accumulate and sequestrate carbon. Regenerating areas during the fallow period of Milpa farming also represents a woody species pool of critical importance with considerable potential for biodiversity conservation(Robiglio & Sinclair 2011). Studies have also shown that shifting cultivation can be sustainable with reduced effects on biodiversity and soil resources, considering that a sufficient fallow length is maintained to allow for sustainability of this practice, increase in biomass, and other environmental goods and services (Robiglio y Sinclair 2011).

Though Milpa farming is an integral part of the Mayan culture and the predominant farming system in Toledo, an increasing population and decrease of land availability may one day result in the increase used of alternative farming practices. The Promotion of Agroforestry systems for example, could very well be part of the solution to managing agricultural lands in Toledo. Based on Levasseur 2000, three types of traditional agroforestry systems though not predominant are already practiced in Toledo: the Milpa (slash-and-burn agriculture system), cacao cultivation under shade trees, and the home garden. The Belize agricultural strategy for Belize recognizes agroforestry systems as being important to the lives of poor farmers, helping to meet a family's needs for food and wood, and income generation(MAF 2003). Agroforestry systems can also help to increase the carbon stocks within degraded forest landscapes, by making better use of sustainable forest management principles, lengthen of the fallow period and the promotion of valuable species in these areas (Levasseur y Olivier 2000; Tschakert *et al.* 2007).

8.1.11Logging as a direct cause of forest degradation.

Many of the respondents can be quoted as stating that "logging not just illegal, but logging as allowed under legal licenses and permits issued by the government of Belize" is a direct causes of forest degradation.

Illegal Logging or the illicit felling of trees in Toledo is done by villagers who usually work for illegal traders, legal traders, local influential leaders and forest land encroachers. Many of the respondents stated that the main reasons for the depletion of valuable timber species is also due to corruption and negligence of Forest Department staff members, local influential leaders and some government officials.

Based on the respondents, often local people are used to harvest, receiving a small salary, way below what should be gained considering the intensity of work required to obtain and extract these species from the forest. With the need to harvest more species adequate to pay fees and household item, the depletion of forest resources mainly timber have increased tremendously. Respondents at the local level responded that the distance traveled to acquire timber products are now twice as far as compared 10 years ago. In particular the popular species such as Mahogany (Swietenia macrophylla) and Rosewood (Dalbergia stevensonii) have become rare today.

The high demand of Rosewood (Dalbergia stevensonii) on the Asian market has resulted in a change of livelihood being reported by respondents resulting in many farmers abandoning their farms and directing efforts to the extraction of timber species for fast cash needed to pay school fees and medical fees which cannot be met by regular subsistence farming. This situation was also evident in Bangladesh where the consumption and market of timber and other forest products increased causing a greater demand for timber and the eventual increase in forest degradation (Ahmed 2008).

Based on the respondent, except for three long term forest licenses issued for logging in the Toledo district, most other legal logging activities are carried out under one year licenses and petty permits. These permits though legal, as explicitly stated within, are not for sustained yield. This implies that no sustainable plans or guidelines are required for exploitation of timber products under these licenses. This permit allows for the extraction of timber not exceeding the amounts of $50Bze ($25us). They are also less strict and demanding of loggers when compared to licenses for sustainable forest management within Forest reserves and communal land which is accompanied by a sustainable forest management plan which allows for 40 years of activity. It is also reported that due to lack of monitoring and enforcement, that these licenses are misused, with way more material being extracted than the allowed amount under these license. This has led to lack of valid data required to analyze the amounts of timber being extracted from the forest and the district.

In particular the respondents expressed that especially contributing to forest degradation is the tremendous increase of petty permits issued by the Forest department with a report increase from between 50 to 60 permits prior to 2006, to 752 issued, in the period 2007-2008.

8.1.12. Recommendation

In order to promote sustainability of timber extraction in Toledo, there is a need for better monitoring of activities carried out under licenses and greater enforcement in reducing illegal activities in the district. Though respondents are aware of the limited human and physical resources to carry out these activities they do not consider monitoring and enforcement as arbitrary activities.

Based on responses, there is also the need for public awareness and capacity building on sustainable forest management activities and greater emphasis and awareness centered on community forest management, especially within communal lands. In the Toledo district three sustainable community forest management plans have been approved for the villages of Conejo, Sunday Wood and Boom Creek respectively.

Under CFM, villages are allowed to use and profit from the forest under a legal license signed by the minister of forestry in Belize. The license is acquired after completing a management plans for activities within the areas developed using the principles of sustainable forest management, ensuring that off-take is kept at sustainable levels. Organization of the communities is normally done within the community, where Communities, setting by-laws and self-regulation measure with regards to access of forest products and profit sharing(CIFOR 2006).

Normally the inclination to take part in CFM can be numerous, such as: a way of maintaining the forest to ensure future use, to ensure a continued supply of firewood and fodder; to enable eco-tourism(CIFOR 2006); the vast majority in Toledo participate, in the hope that this activity will provide a means of sustainable subsistence and an alternative source of income in the future.

Though the CFM plans in Toledo have not begun true implementation, it is hoped that real and tangible monetary gain can be attained.

8.1.13. Underlying causes of Milpa farming and logging in the Toledo district

8.1.14 Milpa: Poverty and unemployment

Based on the results of this research the main underlying cause of both Milpa farming (44%) and Logging (42%), relates to Poverty (livelihood and Job creation).

Livelihood strategies in Toledo are mainly based on agricultural farming; subsistence farming is especially favored considering the limited presence of other industries in the district (NHDAC 2010). Subsistence farming, however, rarely supplies all basic needs of the local population and to complement these needs and as part of their livelihoods strategy, poor people living adjacent to forest areas fall back on forest resources as, reported for example for Bangladesh and China (Ahmed 2008; Démurger y Fournier 2010)

The World Bank describes poverty as "Hunger. Poverty is lack of shelter. Poverty is being sick and not being able to see a doctor. Poverty is not having access to school and not knowing how to read. Poverty is not having a job, is fear for the future, living one day at a time. Poverty is losing a child to illness brought about by unclean water. Poverty is powerlessness, lack of representation and freedom" (TWB, 2008).

This multi-faceted definition of poverty also reflects the situation in Belize and Toledo, where there exist the vast majority of low income communities at the national level. Though the Belize Poverty Assessment refers to the persons of the Toledo district as poor, 73% of the respondent do not consider the people of Toledo as poor stating that they may be cash poor but rich in resources and having a definite awareness of where the next meal comes from. They consider that their basic needs (food, shelter) are being met and that their local communities play a supportive and non-threatening role in maintaining a high level of wellbeing.

Table 4: Rural and urban poverty rates by district

Poverty Rates (Poor/ indigent as % of population)					
District	**Indigent**	**All Poor**	**Town**	**Indigent**	**All Poor**
RURAL AREAS			**URBAN AREAS**		
Corozal	28	70	Corozal	2	17
Orange Walk	18	52	Orange Walk	8	27
Belize	8	32	Belize	6	28
Cayo	18	50	Belmopan/ San Ignacio/ Santa Elena	6	32
Stann Creek	24	53	Dangriga	12	32
Toledo	60	73	Punta Gorda	4	7
Country	**26**	**55**	**Country**	**6**	**28**

NB. The Table shows data for individual (not household) poverty.

(NHDAC 2010)

The view of the respondents is not reflected by the poverty assessment of Belize which shows that rural indigence is more than twice as high (at 60%) in Toledo than all other districts (Table 3). This may be so because though the wellbeing and availability of resources may be present, there is still a need for cash which is required for payment of education and health expenses, thus the need for sale of these timber products and agricultural products from farms. The same was reported in Bangladesh where the lack of alternative livelihood of forest dependent communities forced increased extraction of forest products and the eventual degradation of its forest.(Ahmed 2008). This allows us to conclude that in the Toledo district, poverty is really not the underlying cause of forest degradation, but rather the lack of alternative sources of income.

The rural population in Belize is dominated by agricultural workers who account for almost two thirds of the total poor population. The Toledo district contains 46.1% to the total agricultural sector for Belize, a sector which is reported as containing 20% of the total poor population in Belize, based on income generation, receiving the lowest monthly income of $200us ($400 Bze), insufficient to provide for two adults. (NHDAC 2010).

8.1.15Milpa: Culture and Tradition;

The second underlying cause of Milpa farming as stated by 35% of the respondents corresponds to Culture and tradition. Milpa is a traditional type of slash-and-burn agriculture, practiced for hundreds of years, by the Mayans and other ethnic groups in the district. It is considered the predominant agricultural system used by most communities and farmers, and even more so by the Mayan of rural communities. It is without a doubt the cornerstone of Maya agriculture, and allows them to cultivate corn, rice (Oryza sativa), and beans (Levasseur y Olivier 2000).

Milpa farming is also considered as a social aspect of the Mayan culture, evident by the participation of community member in the preparation of each other's Milpa plots, with no monetary gain expected or given. This practice guarantees sufficient labor force for Milpa farming. The different stages of Milpa farming are organized based on selected annual seasons set aside for, slash and burn, cultivation and harvesting of crops. Milpa farming is generally done by the men, and based on the Maya culture, men are normally responsible for all agricultural production, decisions concerning agricultural planning, and providing most of the labor required(Levasseur y Olivier 2000).

Though modern farmers generally agree to receive training, in more sustainable agricultural practices, the complete turning away from Milpa farming in the traditional sense will be more difficult to achieve, and efforts on reducing its impact on forest will have to consider the cultural implications.

8.1.16Milpa: Education;

Education in the form of formal education, awareness and capacity building was considered by 21% of the respondents to be the final underlying cause of forest Degradation caused by Milpa Farming.

The level of education of the household head is closely associated with the likelihood of a household being poor (NHDAC 2010) and a greater dependence on forest resources. The average highest level of education in the Toledo district is the secondary level, with a 91.6% rate enrollment from the primary school level to the secondary level. (MoE 2009). Notwithstanding this positive enrollment from primary to secondary school, the vast number of secondary school within the country are found in the Belize District with a reported 3 secondary schools in the Toledo district in 2009. The scarcity of secondary level school in the district means lack of attendance due to distance/cost especially for rural communities (MoE 2009).

There is a definite lack of emphasis on sustainable land management practices within the secondary level curriculum. On the other hand, environmental awareness is focused on conservation and not necessarily sustainable practices.

This lack of formal education could be compensated by public awareness and capacity building by the Government institutions in sustainable agricultural practices and forest use. However, respondents did state that, in the Toledo District, the existing awareness is carried out mainly by NGO's (TIDE, Ya'axché, SATIIM and SHI) and not the government institutions which have the legal mandate.

8.1.17Logging: Weak forest law enforcement and governance;

Loss and degradation resulting from weak forest law enforcement and governance have occurred at the expense not only of national economies, but also of the rural people who depend on forest resources for their livelihoods. This translates into enormous national costs. For example, failure to collect appropriate royalties and taxes from legal forest licenses has a global cost to governments of about US$5 billion annually. Illegal logging results in additional losses of forest resources from public lands of at least US$10 billion to US$15 billion a year(TWB 2009). Particularly to Belize, for the period 2006 to 2010 the Government of Belize should have collected the amount of US$440,930 (Bze$881,860) in royalties, however only US$298,422 (Bze$596,845) was collected leaving in arrears 32% of this total.

35% of the respondents stated that weak law enforcement and monitoring has contributed to forest degradation in the Toledo district. The Forest Department has the legal mandate to issue permits for the extraction of forest products, but the lack of resources as resulted in the total lack of enforcement and monitoring of logging activities both legal and Illegal. This lack of resources for enforcement and monitoring has led to the lack of sustainability of logging activities and the failure to meet global Sustainable Forest Management practices aside from the LTFL's issued(Santos 2009).

Based on the respondents, at any given time, no more than 4 Forest Department staff, can be found stationed at the Machaca forest station, expected to attend to the needs of more than 50 villages with minimal allocation of resources to do so. While there is some competent staff in the Department, it is not nearly enough to effectively deal with the daily demands and requirements of its mandate(Santos 2009).

8.1.18 Logging; Poor institutional capacity;

23% of the total group of respondent concluded that Poor Institutional Structures has also lead to forest degradation. The institutional dimension of Sustainable Forest Management should normal encompass national policies, plans, information management, institutional capacities and economic conditions in relation to its influence on sustainable forest management. Regulatory institutions and organizations within a given sector exist to establish a framework and provide direction. These institutions play the role of facilitating and fostering best practices and technologies in the proper management of natural resources (Prins 2008 cited by (Santos 2009).

According to the respondents the institutional capacity for sustainable forest management is considered poor. The respondents share the view that the forest sector of Belize is totally lacking in institutional capacity. It is felt that the sector needs more professionals trained in forestry and forest management, and that the regulatory body should also take the role of extensions staff. The Forest Department, should also be more adequately equipped to support the various facets of forest management (Santos 2009). The respondents are also of the view that forest management

in Belize is politically entwined and that local politicians with no training in forest management should stay out of the affairs when issuing permits at the local level.

There is also the believe the Forest Department falls short in terms of carrying out public awareness of forest use and management and that there exist the needs to revise the sustainability of the forest licenses issued by the forest department under the Forest Act Chapter 213 of the constitution of Belize.

8.1.19ANALYSIS OF LAND/FOREST MANAGEMENT IN TOLEDO

The respondents of this research consider that an even greater understanding of the forces resulting in forest degradation caused by agricultural practices and timber harvest can be reached, by analyzing of the weaknesses and strengths of land/forest management in Toledo. Forest management should not just be limited to the forest sector in Belize but should be highlighted within the portfolios of most ministries of government. Forest play an important role in adaptation and mitigation to climate change as well poverty alleviation agendas of the world bank, thus, its sustainable use should be important to both sectors in Belize. By analyzing land management one is better able to make recommendation using a holistic approach.

8.1.20 Weaknesses of forest management;

This study reveals that the main weaknesses of land/forest management (to expound on a few responded by persons interviewed) stems from the lack of monitoring and enforcement of logging activities under the legal mandate of the FD.

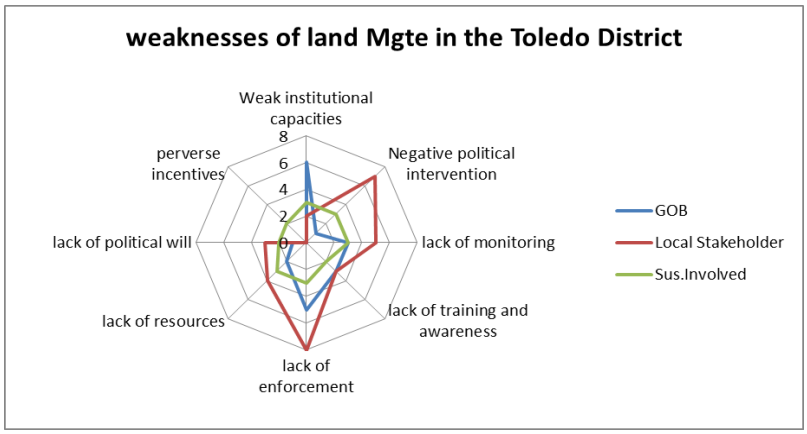


Figure 7. weaknesses of forest management in Toledo

It is believed that with greater political will there will be a higher allocation of resources to both sectors to execute their functions effectively and thus strengthen institutional capacities and structures.

Belize is also host to many antiquated legislative pieces that do not speak or directly translate into sustainability of practices allowed by both the agricultural and forest sector. The presence of perverse incentives due to lack of complementarity of laws, allows in practice one law to override the next. Such is the case where no permit of monetary value is required to establish a Milpa farm. The Milpa system entails slashing and burning of forest cover, or the clearance of forest land for establishment and the use of forest product during the establishment requires no permits.

On the contrary however, a permit with royalty most likely to be paid based on specie, is required to extract any forest product whether for subsistence or commercial purpose. Many of the respondents consider it a deterrent of sustainable forest practices since an average stakeholder will not travel hours to the nearest forest station to request a permit for the extraction of one tree if the same could be felled for the clearance of agriculture at no cost to the interested party (Fig 10).

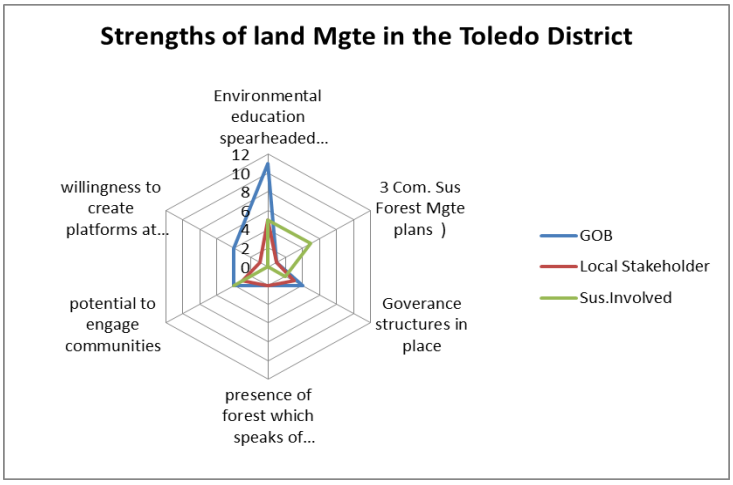


Figure 8. Strengths of forest management in Belize

8.1.21. Strengths

The main strengths identified by respondents of land/forest management by the sectors in the Toledo district are; the endorsement by government of three (3) Community Sustainable Forest Management Plans (CFMP) which shows government's willingness to endorse local stakeholder participation in forest product extraction.There is also willingness by the local stakeholders to improve both the environmental and economic sustainability of their practices granted that environmental education and capacity building continues as promoted by local NGO's (YCT, TIDE, SATIIM and other local environmental groups).

There is definitely the potential to engage communities, through consultation, and local stakeholders, with the willingness to take part in the monitoring of forest use, and management planning of the local stakeholders. The GOB was especially keen on the creation of platform so as to promote dialogue between the different sectors on land/forest management (Fig 11).

8.1.22Recommendations

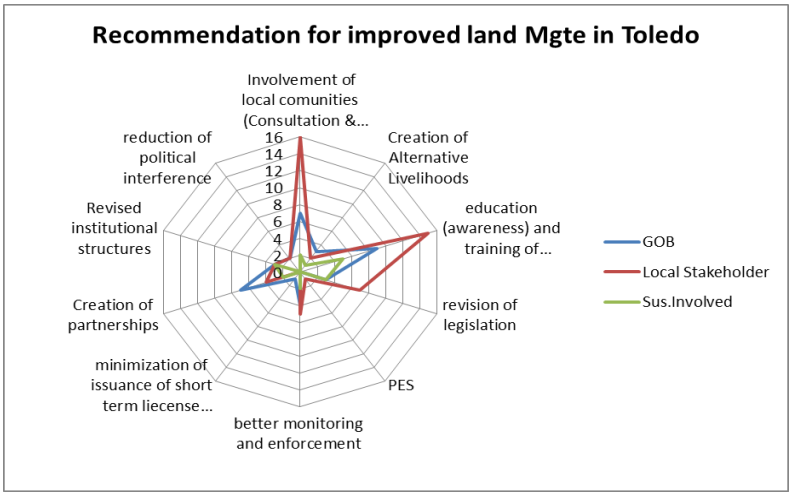


Figure 9. Recommendation for improved forest management

Considering the strengths and weaknesses of forest management, the respondents consider the recommendations (Fig 12) as vital for improving land/forest management and the eventual decrease of degradation in the Toledo district; Increased public awareness and training by both the Forest and agricultural

sector on sustainable practices, can lead to better land/forest management. This can also be enforced via the establishment of extension programs within the both sectors with person trained to impart useful information to stakeholders.

Considering the lack of complementarity of legislative pieces of the sectors, there is a need for legislative revision so as to promote greater sustainability of activities carried out under the permits issued these ministries with the hope of fostering environmental sustainability. Specifically to the forest sector there should be a minimization or pause in the issuance of short term permits until resources and guidelines can be established to foster sustainability of such activities,

Monitoring of sustainability and even degradation will be reliant on an improved database system for both the FD and local agricultural station and may even entail engaging of local political structure (Alcalde and village council) to monitor use.

Lastly, the creation of partnership and opening of dialogue between sectors both at the GOB and local level can be facilitate by the reactivation of old, or creation of round table mechanisms such as the THFI (Toledo Healthy Forest Initiative) (Fig 13).

8.1.23Conclusion

The misconception that forest degradation is solely the responsibility of the forest sector can be kindly placed to rest based on study results such as this. The forest is not only used by person interested in logging but is the source of multiple timber and NTFP's important to the everyday livelihood of many forest dependent communities.

Degradation from human activities is not easily tackled, and the results of this study brought to light the multiple direct and underlying factors which have resulted in forest degradation in the district. Though it may be a daunting task, climate change mitigation and adaptation activities similarly to poverty reduction programs most take these factors into account when promoting sustainable land uses by sectors for the wellbeing of forest dependent people and sustainable national development.

It would be wise to tackle this challenge by considering actions based on recommendations, which may impact change in the immediate future, may requiring the reinvention of practices or condition but rather taking advantage of enabling conditions that already exist. A first step can be the establishment or revitalization of platforms, for improving land management and promoting sustainability spearheaded by the relevant sectors involved in land management and use. This is especially important, as it will facilitate dialogue and prioritize activities for implementation of recommendation.

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9 ARTICLE TWO (2); EXTENT OF FOREST DEGRADATION IN THE TOLEDO DISTRICT OF BELIZE

SUMMARY

Though there has been great emphasis on conservation and sustainable use of forest resources, the ever growing demand of land suitable for agricultural production and the dependence of communities on forest will continue to pose a threat to the integrity of forest that cannot be ignored. This study was implemented with the objective of analyzing the extent of degradation caused by logging and forest regeneration caused by the fallow period of Milpa farming, and the possible link with the geo-spatial features of road and settlement in the Toledo district. Secondly based on literature review and method used in this study, the important components for monitoring degradation were highlight. The research was carried out within the period, January to August, 2012, in the Toledo District of Belize. Toledo is the southernmost district of Belize with over 50 villages, and a population whose main livelihood is generated from forest use.

In studying the extent of degraded forest and forest degradation, this research made use of GIS (Geographic Information System) and Remote Sensing technologies through which a Spectral Mixture Analysis (SMA) was applied on a series of Landsat Satellite Images for the period from 1989 to 2010. This mixture analysis allowed for the estimation of the proportion of different land cover components (vegetation, soil and shadow) within a pixel. Further validation by ground-truthing with the use of GPS was also performed.

A total of 6086.97 ha of regenerating forest from 1989 to 2010 was detected as a result of Milpa farming, whereas 62-289.09ha (including the striping artifact in the 2010 Landsat image), of already existing forest were degraded though selective logging during the same period. An Exponential regression analysis (Non-Lineal) with a level of significance of 90% indicated that there exists a direct negative effect of distance to roads on regenerating forest ($p = 0.0009$) and a Lineal regression analysis with a level of significance of 90% indicated that there exists a lineal relationship of distance to settlements on forest regeneration caused by Milpa farming and density loss caused by logging (respectively $P=0001$ and $P=0.0001$). There exist no effect of distance to roads on density loss caused by logging ($p= 0.5381$).

No method or approach for estimating the extent or monitoring of degradation is without limitations. Notwithstanding the method used one should definitely take into consideration all factors that facilitate degraded forest in the local and well as regional context. Even more useful might be the modeling of degradation, taking into account the socio-economic and geographical factors that may be linked to degrading processes.

1.9 INTRODUCTION

9.1.1 Statement of the Problem

Reducing Forest degradation is integral to mitigating and adapting to climate change and just as important is the promotion of sustainable use of its resources in maintaining the lives of forest dependent communities. Forests contribute to the livelihoods of more than 1.6 billion people with the forest products industry serving as a source of economic growth and employment reaching US$270 billion(TWB 2009).

Though one would want to focus on the conservation and sustainable use of forest resources, the ever growing demand of land suitable for agricultural production will continue to pose a threat to the integrity of forest which cannot be ignored. The agricultural sector is one of the major sectors in the economy of Belize, accounting for little over 10% of the gross domestic product (GDP). Particularly to the Toledo District, Agriculture accounts for 46% of the employed population compared to 16% in the Belize District (NHDAC 2010). Most other necessities required by persons in Toledo, particularly at the rural level are primarily obtained directly from the Forest or from local shops within the district.

9.1.1.1 Milpa farming

Photograph 1. Land after slash and burn

The main agricultural practice in Toledo is Milpa farming (Slash-and-burn). This system has received a great deal of attention given its observed role in biodiversity loss, change in forest structure and by large its contribution to global warming and providence of ecosystem goods and service (Fujisaka *et al.* 1996).

As with other Mayan groups in Central America the Mayan communities in Belize continues to rely upon forested areas as integral components of their agricultural systems. (Diemont *et al.* 2011). Mopan Maya utilize primary forest, known as old nuk che, for selective timber cuts, hunting, and gathering of food, medicines, and firewood (Diemont *et al.* 2011).

This agricultural technique has shaped the landscape in the Toledo district for hundreds of years. These generally start with a patch of forest being cleared through *slash and burn* (trees are knocked down and burnt) and the resulting land cultivated with different crops. The main crops cultivated are corn, beans, and occasionally rice, cassava, coco yam, plantains, banana, pumpkin, pepper, calaloo and ockra.

Based on the Milpa system a plot will be used until the farmer detects a decrease in productivity and this area left to regrow through natural vegetation for several years with the hope of regaining soil nutrients for subsequent cultivation. This regrowth period is called "*fallow period* "which traditionally lasts between 10 and 12 years, allowing for soil fertility replacement.

Traditionally farmers within a village possess several plots (approximate 1-2 ac in size) which are rotated with one active plot and several plots in fallow within a given time frame. This however has changed in the last decades, due to population increase and shortage of lands prompting the use of land successively, without allowing for the fallow period, or with a much shorter fallow period when compared to the past.

Traditionally corn was planted once a year, in the month of May, which due to the rich nutrient content of soils, translated into a high production providing corn which lasted until the following year. This also has changed (according to the locals), with decreased yield in the last decades resulting in a corn harvest insufficient to last for a year.

In the modern context corn is cultivated twice a year, in May (*slash and burn*, known as *Milpa*, which uses fire to clear the vegetation) and in November (known as *Mata-hambre*, in Spanish literally "Hunger kills") without the use of fire, known as "*slash and mulch*".

Generally, *slash and burn* is applied to a full grown forest, either old growth forests or long fallow period forests, whereas *slash and mulch* is applied to relatively young growing vegetation. Both *slash and burn* and *slash and mulch* can be applied to the same plot in an alternate way throughout the years.

The combination of both techniques, *slash and mulch* and *slash and bu*rn, its rotary nature and the variable *fallow period* scenario have generated a very complex agricultural matrix in a mainly forest dominated landscape. One year old abandoned patches are normally grass dominated, while 2 to 3 year old abandoned parcels are rich in shrubs and small tree between 2 and 4 meters high. 5 to 10 year old fallow patches, are characterized by dense tree cover of thin trees that can reach 10m in height for fast growing species. One can also observe patches of 15 to 20m high trees, in areas where conditions are presumably not adequate for agriculture production, due to the slope gradient or the presence of rocks.

Based on Levasseur 2000 the farming system in the San Jose Village of Toledo which follows the modern agricultural slash and burn practice, was reported as contributing to the problem of forest degradation by fragmentation (Levasseur y Olivier 2000). Milpa farming has also resulted (during fallow period), in the presence of regenerating forest (lacking in parameters that constitutes a fully functional forest, based on the 2006 FAO definition of Forest).

9.1.1.2 Logging

Photograph 2. Logging activity in Toledo

Based on personal interviews during this study forest degradation by canopy reduction has been caused by logging in the district. Many of the respondents were quoted as stating that "*logging not just illegal, but logging as allowed under legal licenses and permits issued by the government of Belize*".

Illegal Logging or the illicit felling of trees in Toledo has been done by villagers who usually work for illegal traders, legal traders, local influential leaders and forest land encroachers. Many of the answered stated that the main reason for the depletion of value timber species are also due to the corruption and negligence of some FD staff, local influential leaders and some government officials.

Often the locals are used to harvest receiving a small percentage of the marketable value of these species. Due to this ruthless profit-making, the depletion of forest resources mainly timber has increased tremendously. Respondents at the local level responded that the distance once traveled to acquire timber products were now twice as far when compared to 10 years prior. The marketed and popular species such as Mahogany (Swietenia macrophylla) and Rosewood (Dalbergia stevensonii) have become rare day by day.

Due to Scarcity of Timber product outside of protected areas the rush for timber (meeting harvestable standards) has reportedly been on the increase, especially for timber valued for furniture making. More so has been the impact of the exportation of Rosewood (*Dalbergia stevensonii*) (the local fast cash specie) on the Asian market. This species found highly within the forest of the Toledo district is used for heavy and decorative wooden furniture, doors and windows of houses.

The high demand of rosewood on the Asian market has resulted in a change of livelihood being reported by respondents resulting in many farmers abandoning their farms and directing efforts to the extraction of timber species for fast cash needed to pay school fees and medical fees which cannot be met by regular subsistence farming. This situation was also evident in Bangladesh where the consumption and market of timber and other forest products increased causing a greater demand for timber and the eventual increase in forest degradation (Ahmed 2008).

Based on the respondents most of the legal logging in Toledo is done under unsustainable licenses. This explicitly states within "not for sustained yield". These licenses, though legal, do not promote sustainable forest management, as the permits are much less strict and demanding of loggers when compared to licenses for sustainable forest management within Forest reserves and

communal land, which is accompanied by a sustainable forest management plan which allows for 40 years of activity.

9.1.1.3 Effect of roads on forest

The presence of roads in Belize has been mainly determined by the need of accessibility from one village and town to the next. Roads have especially allowed rural communities to find sale for agricultural and other products on the local market(Chomitz y Gray 1996). This pattern is clearly seen within the spatial connectivity of the entire road network in Belize which follows a definite pattern of road leading to settlements and towns.

In general roads are often built by governments for a variety of reasons including the desire to provide better access to timber resources, to promote farming or for national security reasons (CIFOR 2000). Rural roads especially promote economic development though specificity of use depends on the land's physical productivity (Chomitz y Gray 1996). Market access and distance to roads strongly affect the probability of agricultural use especially for commercial agriculture in Belize.

Roads are closely associated with deforestation, and thought studies have not yet been conducted in Belize as to the extent of its effect on degradation, in the Brazilian state of Par, deforestation following road construction increased from 0.6% to 17.3% of the state’s area between 1972 and 1985(CIFOR 2000). Cases such as these have made it important to quantify the impact of roads on both forest loss and development in order to assess the severity of the trade-off between environmental reservation and economic growth(Chomitz y Gray 1996).

Roads facilitate increase of use of an area by humans, who often cause diverse and persistent ecological effects. New roads increase ease to access by humans into formerly remote areas. Perhaps more important, roads often increase the efficiency with which natural resources can be exported(Trombulak y Frissell 2001).

The writer considers it imperative that one considers that forest density loss and the increase in degraded forest area are not always caused by a single culprit, but can be a much more complex situation, and the effect of a single force, such as poverty or roads, is very difficult to ascertain (CIFOR 2000).

9.1.1.4 Effects of settlements on forest

Like most rural populations in developing countries, the communities of the Toledo district rely overwhelmingly on their environment for subsistence, with a great dependence on natural resources such as fertile soil, fresh water, and forest resources. Population pressure for these resources has endangered the productive and ecological function of these areas. This has resulted in demand for land cleared for agriculture systems. This sort of unplanned land management has

led to a degradation of natural environment by inappropriate use of resources, resulting in the loss of ecosystem goods and services (Binford 2007).

9.1.2 OBJECTIVE OF STUDY

An important development in recent years has been, the extension of satellite based remote sensing and spatial data to move beyond a focus on immediate forest change, and attempt to understand the human and biophysical drivers of forest change. This research was implemented with the objective of analyzing the extent of degradation in the Toledo district and possible relations to the geo-spatial features of settlements and roads. And to determine important components for monitoring forest degradation.

- What is the extent of degradation in the Toledo district?

For the purpose of analyzing the possible effect of Roads and settlement on density loss and regeneration the following Hypothesis were analyzed;

- $H_{o:}$ there exist no effect of distance to roads /settlements on forest degradation
  H_1: There exist effects of distance to roads/ settlements on forest degradation

For the objective of determining important components for monitoring forest degradation the following questions were used;

- What are the characteristics of a good monitoring system?
- Can existing methodologies for monitoring be adapted to the Toledo district?
- Should local populations play a role in monitoring forest degradation?

9.1.3 JUSTIFICATION

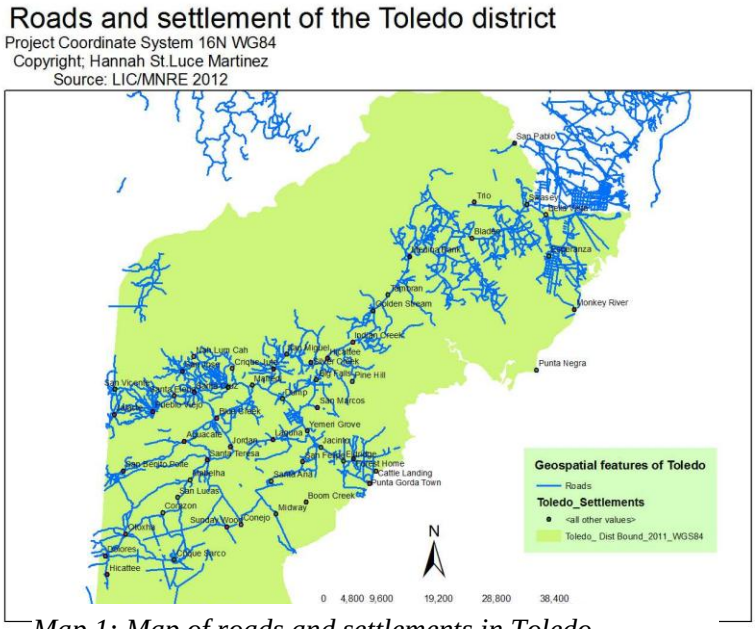
Forest degradation usually occurs slowly and the effects of activities that produce forest in a state of degrade are not always evident within a short time frame. Therefore improved understanding of these complex processes is of vital importance with great emphasis being given to scientific research into the causes and effects of land use and land cover changes (Pineda *et al.* 2010; FAO 2011).

Promising for Belize is that remote sensing technologies, free or affordable, are increasingly used to monitor landscape change in many parts of the world. Using imagery from various satellite sensors, the calculation of the extent and patterns of degradation has been made relatively easy to achieve, providing the adequate software and skills.

In fact, satellite imagery is considered by some to be the most reliable source of quantitative information about degradation in the tropics(Rinku 2006). Taking advantage of these techniques is timely, since the growing demand for forested lands in the Toledo district especially for timber and for agricultural cultivation, will certainly not decrease in years to come.

9.1.4 MATERIAL AND METHODS;

The Toledo District is one of seven found in the country of Belize. Belize is located between 15°52' and 18°30' North Latitude and 87°28' and 89°14' West longitude, the second smallest country in Central America, measuring 280 km from north to south and 110 km from east to west with a land area of 22, 963 km2 . Topographically, the country is divided into two physiographic regions: the northern lowlands and the Maya Mountains dominated. The southern plains and Maya Mountains are dominated by sub-montane and montane broad leaf forest interspersed with pine (*Pinus caribaea var. hondurensis*) savannas (Young 2008).



Map 1: Map of roads and settlements in Toledo

The district is also center to Belize's Mayan population. Villages here tend to be smaller and more dispersed than in the rest of the country, where many are located along the major roads. According to the 2010 census, Toledo District has a population of 30,538 persons, with at least five distinct cultures contributing to its rich cultural heritage.

Toledo produces significant proportions of the country's rice, corn and peas, almost entirely from small farms. Traditionally, Toledo has been the poorest district in the country, partly due to its peripheral location relative to the rest of the country's administrative, commercial and tourist centers(NHDAC 2010).

Land in the Toledo District, except for a few private plots and communal lands is owned by the State (Levasseur y Olivier 2000) with nine (9) Protected areas of National Park, Forest Reserves, Nature Reserves and Marine Reserve categories as well as some other Private Protected Areas.

Table 5: Summary of the road network in Belize

DISTRICT	MAIN ROADS	SECONDARY ROADS	FEEDER ROADS	TOTAL MILES
BELIZE	65.6	62.6	73.2	201.4
CAYO	87.7	34.5	231.2	353.4
COROZAL	27.4	108.4	241.5	377.3
ORANGE WALK	26.7	60.6	312.0	399.3
STANN CREEK	102.1	83.4	136.4	321.9
TOLEDO	46.5	96	83.4	225.9
TOTAL MILES	356	445.5	1,077.7	1,879.2

(MoWT 2001).

The road network in Toledo is made up of 46.5 km of main road, 96km of secondary roads and 83.4miles of feeder roads with a total of 225.9 miles of road in the entire district (Table 4).

The Toledo district is composed of flat coastal plains, gently rolling foothills and undulating lowlands. The relatively high Maya Mountains reach about 1 000meters in elevation. The uplands are classified as wet sub-tropical, with annual precipitation of 3 000 to 4 500 mm, while the lowlands, with a yearly rainfall of 2 000 to 3 500 mm, have a wet tropical climate. Severe storms, which sometimes significantly damage crops, occur in the wetter season (June to November) (IFAD 2007).

9.1.5 METHODOLOGY

9.1.5.1 DEFINING FOREST, FOREST DEGRADATION, DEFORESTATION AND DEGRADED FOREST

For the purpose of this study a workshop was conducted with persons from varying sectors (Appendix 4), with the objective of adopting definitions for forest, forest degradation and deforestation in the Belize.

For the purpose of monitoring and reporting to the different conventions and bearing in mind the importance of forest within the local context the definitions as adopted are as follows

- Forest: *"Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ(FAO 2006 cited by* (FAO 2007)

- Deforestation: *"The conversion of forest to another land use or the long-term reductions of tree canopy cover below the minimum 10 percent threshold which constitutes forest.*" (FAO 2001 cited by (FAO 2007))

- Forest Degradation: *"Changes within the forests that negatively affect the structure or Function, and thereby lower the capacity to supply products and/or services."* (FAO 2006)

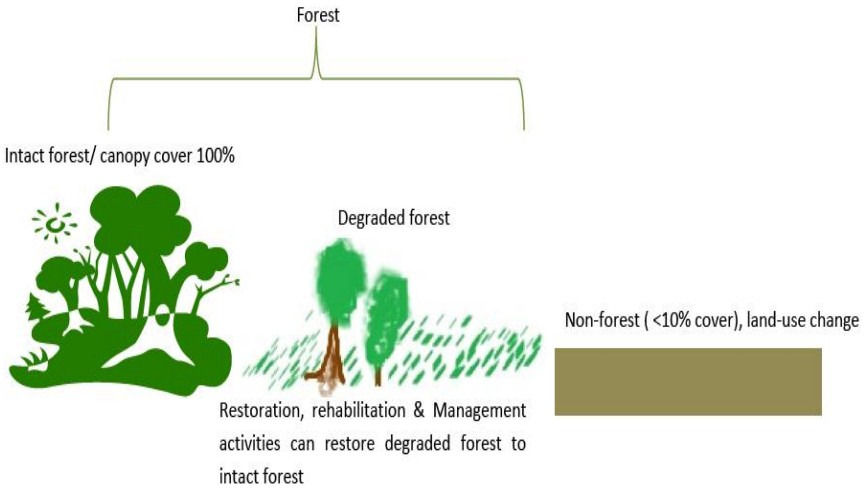


Figure 10. Degradation Process

If one were to base on the FAO's definition of degraded forest, forest in degraded states are considered as having an altered forest structure, crown cover, species composition and stocking. This forest area may have a reduced capacity, when compared to the original forest, to provide goods and services and others functions with limited or no productivity(Lund 2009). In other words degraded forest is neither here or there, but has the definite ability through rehabilitation, restoration and management to regain functions similar to the original forest it replaces *(Fig 13).*

Based on the above use of the terms, the forest of Toledo is comprised of a mosaic of intact forest, degraded forest, agricultural uses among others. This definition allows us to classify forest during the fallow period of Milpa farming, as well as other areas with vegetation growth with the potential to retain full functionality in situ, as forest though in a state of regeneration.

9.1.5.2 GIS METHODOLGY FOR ANALYZING REGENERATING AREA

Detection and mapping forest degradation with remotely sensed data is more challenging than mapping forest conversion because of the complexity of the degraded forest, with a mixture of different land cover types in one pixel (vegetation, dead trees, soil, shade), causing a mixed pixel problem. In these degraded forest environments, the reflectance of each pixel was decomposed into fractions (in percentage) of green vegetation (GV), soil and shade through a Spectral Mixture Analysis (Gofc-Gold 2010).

For the analysis of forest regeneration caused by the Fallow period of Mipa farming, the 2011 Ecosystem Map of Belize (BERDS 2012) in combination with the SMA results, was used, and a polygon including the areas classified as Agricultural uses, Shrub land and urban areas was

included (as sometimes regrowth secondary forest is classified as Shrub land or there can be agricultural plots within the so considered urban area). All the forest pixels for all of the dates were clipped using this polygon, so that only forest pixels within agricultural use, or shrub land and urban areas were succumbed to this analysis. Once this was accomplished, raster algebra was applied to the generated files. Through the "Raster Calculator" tool, pixels where selected fulfilling the following conditions (and according to the agreed definition of forest):

- Earlier date: % vegetation in pixel <10
- Middle date: % Vegetation in pixel >10
- Later date: % vegetation in pixel>10

Year combinations used were the following sequences: 1989-1994-2000, 1994-2000-2004 and 2000-2004-2010.

When analyzing the effects of the distance to the closest road or the closest settlement, all pixels falling under this category during the period 1989-2010 were added up in a single raster file. Buffers for the roads and the settlements where created using the tool "Create buffer", ", and raster algebra was applied in order to find regenerating forest at a given distance interval.

9.1.5.3 GIS METHODOLGY FOR VEGETATION LOSS/ FOREST DEGRADATION CAUSED BY LOGGING

As this analysis focused on degradation in existing forest cover, all pixels classified as forest in the Cherrington 2010 study were selected, and through an "Extract by mask" procedure (ArcMap10), these same pixels were selected for the 1989, 1994, 2000 and 2004 SMA results (in raster *.img* format).

Unlike analyzing regeneration all forest pixels were used for this study. This kind of degradation has been assigned to areas where % of vegetation cover has seen a persistent decline or decline in at least 2 consecutive dates (i.e. a pixel of forest where % of vegetation cover for the years 1989, 1994 and 2000 has been 1989>1994>2000). In the "Raster calculator", the condition for the selection of pixels was as follows:

- % vegetation in Earlier date
- < % vegetation in Middle date
- % vegetation in Middle date > % vegetation in Latter date

Two (2) different datasets referred to degradation through vegetation cover decrease, the first one consisted of all degraded areas based on the individual periods of time 89-94-00, 94-00-04 and 00-04-10 and the second (used to analyze the distance to roads and settlements), which included only the pixels that had experienced persistent decline or at least decline twice (2 times) during the period (1989-2010). The figures of total decline in ha vary for both approaches, since ruling

out the pixels with the occurrence of this process once resulted in the reduction of the initial figures.

This process allows us to state that the statistics for vegetation density loss referring to their proximity to roads and settlements solely applies to pixels of forest that have seen continuous forest degradation during the period 1989-2010, more closely linked to human induced decline.

Three factors can be said as contributing to the total amount of forest degradation detected during the 2000-2004-2010 period:

- the actual loss of vegetation caused by human factors like selective logging,
- the damage produced by Hurricane Iris in 2001,
- and the artifact created by the striping in the 2010 Landsat image (caused by a failure in the Landsat ETM+ sensor in 2003)
-

For these reasons, and the objective of this paper of analyzing the influence of human induced factors on forest degradation, only the pixels where this degradation process had happened twice (2 times) and above were used, ruling out the vast majority of artifacts generated by the satellite image striping and hurricane damage which would also be followed by regeneration similar to the one described in the previous section.

One may argue that this process has resulted in the loss of information, but as explained above, the pixels selected reflect an anthropogenic origin of the degradation presented in this section.

Images

The Landsat Satellite images used in this study have been obtained thanks to Emil Cherrington and CATHALAC, who shared radiometrically processed, mainly cloud free Landsat images with the following characteristics (Table 6):

Table 6: Specification of images used in study

Date	Satellite	Sensor	Spatial resolution	Spectral resolution	Path	Row
28/12/1989	Landsat 5	TM	30m	0.45-2.35µm	19	49
28/3/1994	Landsat 5	TM	30m	0.45-2.35µm	19	49
28/3/2000	Landsat 5	TM	30m	0.45-2.35µm	19	49
27/1/2004	Landsat 7	ETM+	30m	0.45-2.35µm	19	49
28/2/2010	Landsat 7	ETM+	30m	0.45-2.35µm	19	49

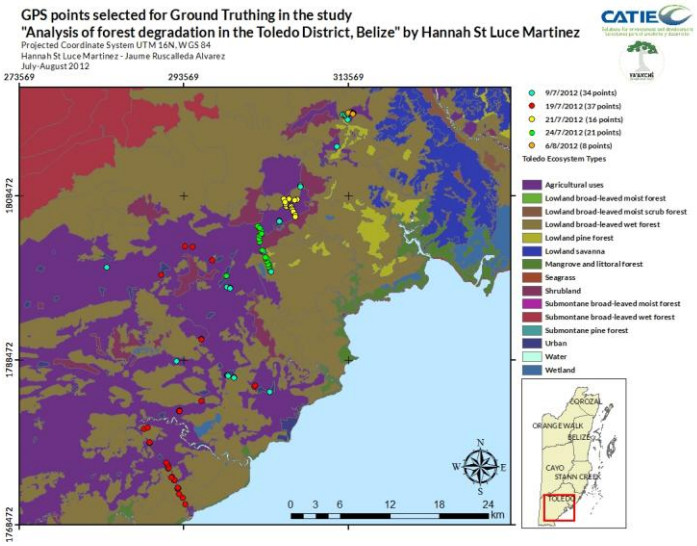
Secondary sources were used to analyze data; these included data from census at the district and village level, records and database from the Forest and Land Information Center of the Government of Belize, published articles, and recent reports from various Ministries of government.

Regression Analysis

A Lineal/Exponential Regression analysis was done to study the functional relationship between the response variable (degradation) and the regresor variables (road and settlement). This regression examined the relationship in roads and settlements separately and their effect on the response variable of forest degradation caused by Milpa farming or anthropogenic causes such as Logging. The buffers created for this analysis was done solely with areas that had suffered forest decline 2-3 times linked to anthropogenic activities

Weights of Evidence analysis

A weights-of-evidence (WOE) analysis was performed to understand the presence of degradation in relations to distance to roads and settlement. (WOE) modeling is a GIS-based technique for relating a point pattern for locations of discrete events with several map layers(Agterberg & Cheng 2002). Comparing two land cover map in different dates, the 1989 map was classified as the base map and the 2010 map as final map cover for computing the transition matrix). The WOE model allowed us to categorize the continuous quantitative variables displaying in graph format the weights of evidence with respect to distance to roads and distance to settlement (Follador *et al.* 2008). This analysis was carried out in Dinamica EGO, a software for Modeling Environmental Dynamics(Soares-Filho *et al.* 2009). Base maps were generated in Arcmap using buffers for the roads and the settlements using the tool "Create buffer", and "Raster calculator".



Map 2: Areas ground-truthed during research

Ground-truthing

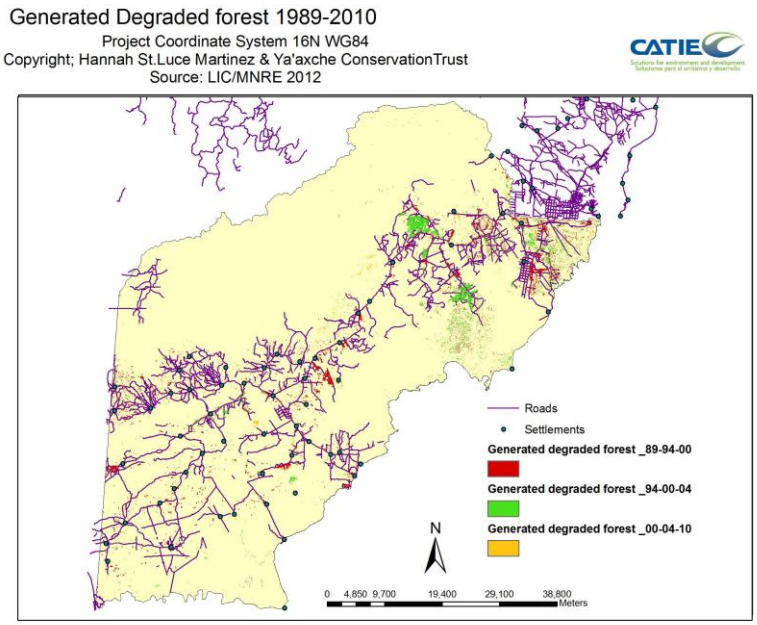
Ground-truthing was done within a timeframe of two weeks and involved the truthing of points based on preselected areas within the satellite images. The use of handheld GPS's was made for this activity with data on the state, height, distance to road, distance to settlement and percentage of vegetation cover being recorded for each point. Due to the inaccessibility to certain points alternative areas were selected on the ground (Map 2).

Constraints

The ground-truthing stage was constrained by the lack of resources, inaccessibility to certain points and the short time frame of this study.

9.1.6 RESULTS;

9.1.6.1 Extent of forest regeneration caused by agricultural practice in the Toledo district



Map 3: Areas of regeneration between the period 1989-2010

Based on the SMA (Spectral Mixture Analysis) of the Landsat images we detected the regeneration of forest caused by the Mayan agricultural practice of Milpa Farming. These areas of regrowth may be structurally and composition wise different from the original forest before slash and burn (Map 3). These areas were detected within the areas classified as Agricultural uses, shrub-land and urban areas in the 2011 Ecosystems Map of Belize(Appendix 1) (BERDS 2012)

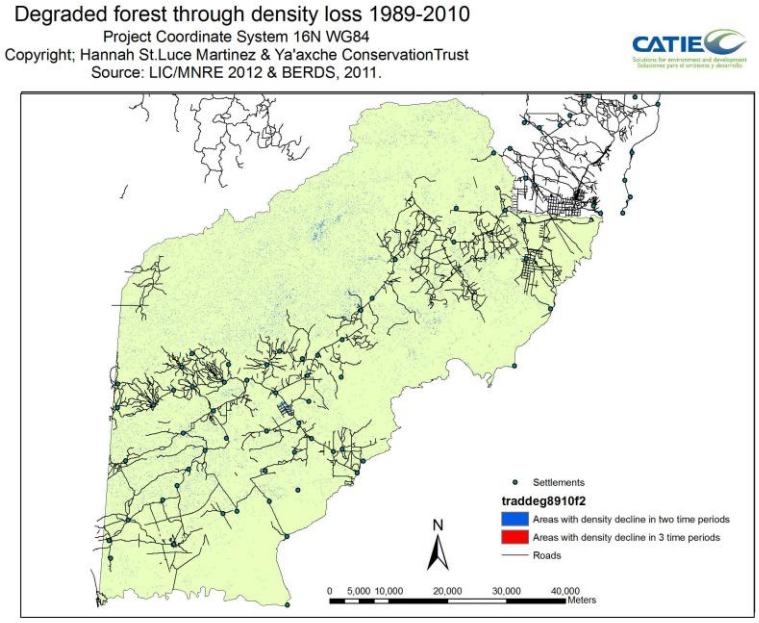
Map three (3) depicts areas where regrowth of an un-structured, sub-functional forest was detected after deforestation. The areas present vegetation covers with little or no structure and with a presumed lower ecological and economical value. Regrowth was observed adjacent to roads and in the vicinity of villages and settlements in the Toledo District.

Table 7: Regenerating areas for selected time frame

Period	**Area (ha)**	Source raster file
1989-1994-2000	4063.14	deg89_94_00_A
1994-2000-2004	1072.89	deg94_00_04_A
2000-2004-2010	950.94	deg00_04_10_A

From 1989-2010 a total of 6086.97 ha of forest generated during the fallow period of Milpa farming

9.1.6.2 Extent of forest degradation caused by loss of vegetation cover density in the Toledo district



Map 4: Illustration of forest degradation caused by loss in vegetation density from 1989-2010

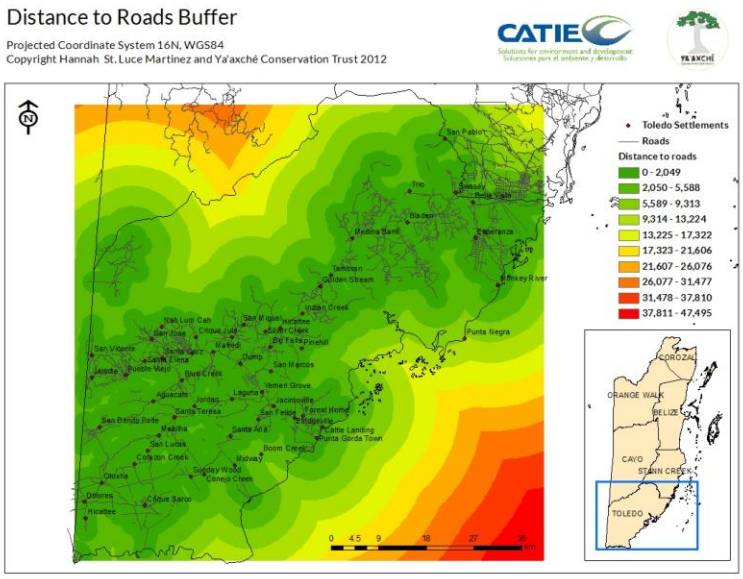
Based on the GIS analysis, loss in vegetation density was highlighted in areas classified as forest in the Cherrington 2010 study in the Toledo district. The areas highlighted in blue, and red are the areas with observed forest decline within at least two studied timeframes from 1989 to 2010, which was made evident by decrease in vegetation cover. This vegetation decline can be observed over the full extent of the Toledo district (Map 4). Vegetation density decline is also detected in areas classified as protected areas in Toledo. And warrants further ground truthing for validation.

Table 8 Sum of density loss based on time frame analyzed

Period	*Area (ha)*	Source raster file
1989-1994-2000	*13786.92*	traddeg_8900f
1994-2000-2004	*25785.72*	traddeg_9404f
2000-2004-2010	*22455.45*	traddeg_0010f

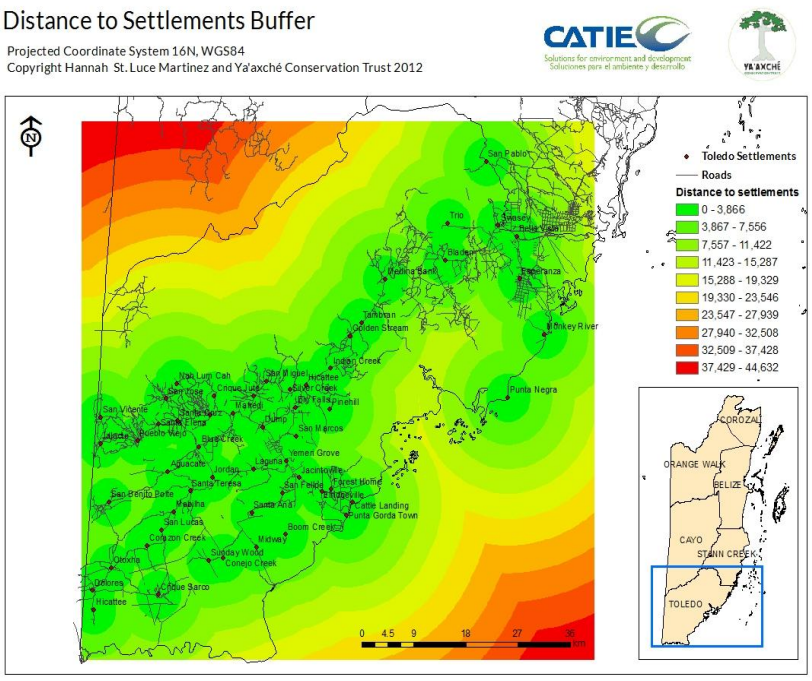
Density loss for the period 1989 – 2010 was calculated as 62,028.09 ha. Times series including the year 2001 saw an increase of area with vegetation decline which may be linked to hurricane damage as explained in previous sections (Table 9).

9.1.6.3 Relationship between forest in degrades state/density loss and the geospatial feature of roads



An Exponential regression analysis (Non-Lineal) with a level of significance of 90% indicate that there exists a direct negative effect of distance to roads on regeneration caused by Milpa farming (p=0.0009). Decrease of regenerating areas with increase distance away from roads. There exist no effect of distance to roads on density loss caused by logging (p= 0.5381).

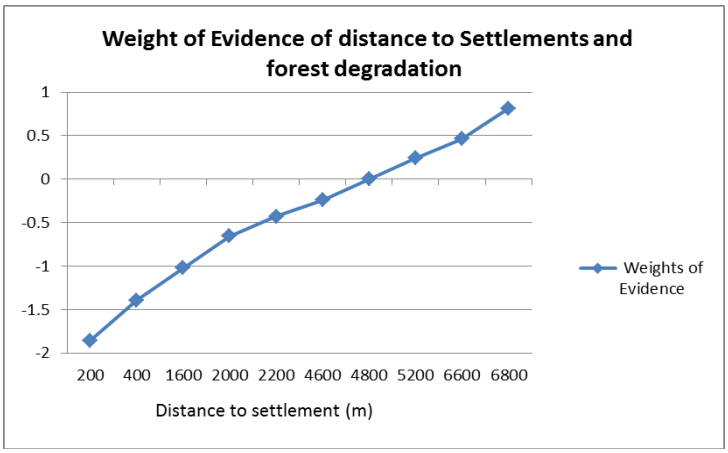
Map 5:Illustration of buffer created to analyze the effects of reads on Milpa farming and logging in Toledo



A Lineal regression analysis with a level of significance of 90% indicate that there exists a relationship of distance to settlements on forest regeneration caused by Milpa farming and logging (respectively P=0001 and P=0.0001).

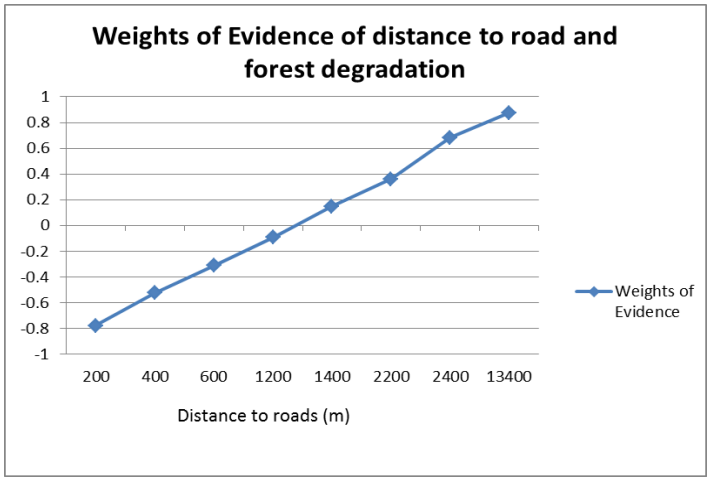
Map 6:Illustration of buffer created to analyze the effects of settlements on Milpa farming and logging in Toledo

Weights of evidence of distance to roads/settlements and density loss



Graph 1: WOE of distance to settlements and logging

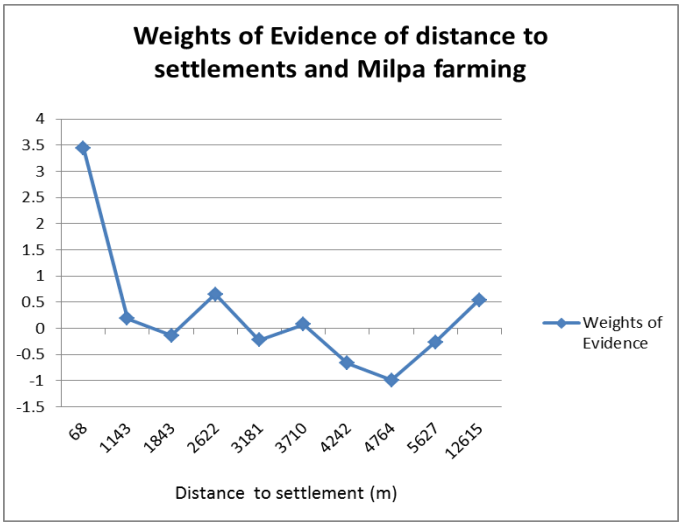
Weights of evidence analysis with intervals of 200m indicate that there exist no positive weight of vegetation decline caused by logging before 4800m to a selttlement. (Graph 1). Effectos of logging are felt further away from settlement.



Graph 2: WOE of distance to roads and logging

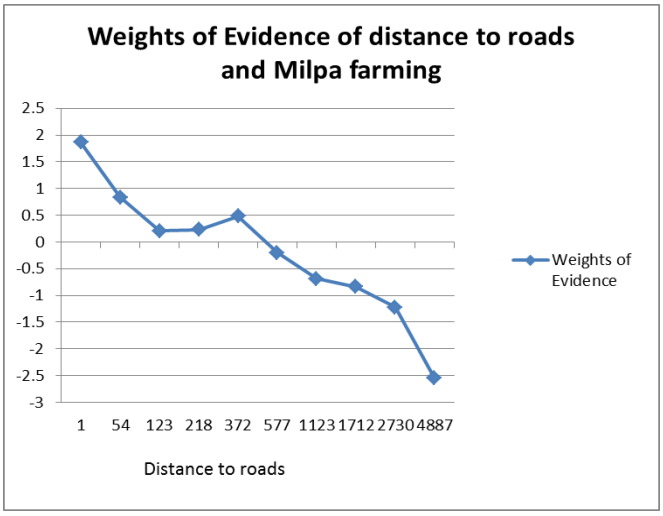
As it relates to roads the WoE analysis shows that there exist no positive weighted effect of vegetation density decline close to roads. Once again positive effect of logging are recorded with increased distance. For the case of Toledo degradation of positive effects occur at approximately 1300m away from roads (Graph 2).

9.1.6.4 Weights of evidence of distance to roads/settlements and forest regeneration caused by Milpa farming.



Weight of evidence analysis, with random program generated intervals, shows that there exists a positive effect on regeneration caused by Milpa farming with closer proximity to settlements, and a declining effect with increased distance away from settlements (Graph 3).

Graph 3: WOE of distance to settlements and Milpa farming



Finally the WOE analysis shows a declining weight of regenerating forest caused by Milpa farming with increased distance from roads. Regenerating areas are found closer to roads (Graph 4)

Graph 4: WOE of distance to roads and Milpa farming

9.1.7 DISCUSSION

1.9.1 Vegetation cover decrease

Statistically there exist no effect of distance to roads on vegetation cover decrease caused by logging (p=0.5381). There is however a lineal effect of settlement (p=0.0001), with increased

density loss as one travels further away from settlements in Toledo (also evident in the WOE analysis).

Photograph 3. Foot paths

Forest density loss caused by logging and or other anthropogenic activities in Toledo is widespread with no apparent dependence or influence to any major road or link to particular settlement; this could be caused by the scarcity of marketable species reaching harvestable size adjacent to settlement or town outside of protected areas. Many respondents informed that the distance traveled to harvest timber has more than double, with species of harvestable size being found further away from the villages.

While traveling through Toledo, a network of trails or foot paths now appear entering forested areas which by all account are used for the extraction of forest products. This network of roads close to villages gives response to the question "How is forest product extracted, if not by primary or secondary roads? The use of these trails may be facilitating the
extraction of forest products. The writer recommends a more in depth study to analyze the environmental impact and extent to this network or trails on the forest.

Studies have shown a direct link of roads as a proximate cause of forest degradation during the construction phase and the eventual link as an underlying cause due to its facilitation of other anthropogenic causes and change in land-use. In Brazil federal roads built to connect the Amazon region to other parts of Brazil stimulated in-migration by landless families as well as capitalized ranchers, loggers, and mining firms, and by the late 1980s, massive deforestation was taking place in the name of regional development, a trend that continues today(Arima *et al.* 2005).

In countries such as Brazil road building involves the extension of infrastructure by individuals on site seeking resources for private benefit such as logging companies who construct new roads (Arima *et al.* 2005). In Toledo, roads are not primarily constructed by persons carrying out logging excepting under Long Term Forest License. It is believed that the average village harvesting does not have the financial capacity to develop such roads as would loggers in Brazil. What is observed is an increase in the trail network to facilitate forest product extraction.

9.1.7.1 Milpa farming;

The extent of regenerating forest caused by Milpa farming, from a visual perspective, are closely linked to both the presence of road and settlement (Fig), with a high concentration of regenerating forest along the network of roads and settlements in Toledo. This was supported by

the lineal regression analysis with a level of significance of 90% which indicates that there does exists a lineal effect of distance to roads and settlements on regeneration (regrowth) caused by Milpa farming (p =0.0009 and p=0.0001 respectively).

The results of the WOE analysis also coincide with what was observed on the ground, showing a declining effect of distance away from road and settlement on forest in regeneration. The landscape of Toledo's rural areas is dominated by Milpa farms and secondary forest along the perimeter of most villages visited during this study. Chomitz, 1996, observed that particularly closer to town, the probability of agricultural use was just 15.2% at the road, dropping below 1% at 5 km from the road. At just 50 minutes (on-road) to town, the probability of agricultural use is only 1.2% at the road, dropping to 0.6% 1I km off the road(Chomitz y Gray 1996).

In general productivity at distinct points in a landscape is facilitated by road access, distance to market, and the productivity of the land (soil). market access coupled with distance to roads strongly affect the probability of agricultural use(Chomitz y Gray 1996).

Chomitz in 1996 in the study of "Roads, Lands and market and their effect on deforestation in Belize, reported that Milpa farmers and other small farmers, are less sensitive to distance to market and to road (Chomitz y Gray 1996) due to the marketing of only a fraction of their produce. As such though this study shows that there is a relationship to roads and settlement, they may not be the only important factors in farming practices. Newly opened roads with good soils experience some forest conversion to semi-subsistence cultivation and, almost certainly Milpa farming, with substantial environmental consequences.

On the inverse, roads constructed into remote areas with poor soils, lead to little or no economic gains to counter balance the expenses of road-building. The presence of roads with poor soils produces little or no impact on forest cover due to farming but could expose the forest to various forms of degradation, such as over-extraction of timber species for commercial purposes(Chomitz y Gray 1996).

9.1.7.2 Recommendations

It is recommended also that Belize develops markets for crops that are appropriate for production in agroforestry systems, intercropping, or for intensive cultivation within small areas (e.g., high value crops). Such market improvements would help stimulate a process of intensification and diversification(Shriar 2001), and lower the great demand for forest conversion which is limited by land availability. The lengthening of fallow periods will also allow for greater productivity of timber product extraction, carbon accumulation and the creation of alternative livelihoods at the rural level.

These areas in regeneration of secondary forests on previously agricultural cleared land in the Amazon have become a promising element within a generally pessimistic scenario. This has

stimulated efforts to augment the value of secondary forest by inducing farmers to increase the use of secondary forest for timber production, agroforestry systems, increase in carbon stocks and a return of soil fertility (Smith *et al.* 1999; MAF 2003; UNEP/CBD 2012).

Recommendations such as these should not be seen as unachievable as many of these practices on limited scales are already in place in Belize and other Central American countries that serve as examples that can be replicated at the local Toledo Level. What definitely must be ensured is that the relevant institutions recognize and adhere to their legally mandated roles in promoting better land use practices for sustainable national development benefiting all, especially forest dependent communities.

9.1.8 Conclusion

Science in itself is prone to limiting factors, but the development and improvement of methodologies and technologies are promising for acquiring more sound results. Many may question the method engaged in this study, due to its limitation of not taking into account others aspect that facilitate forest degradation in the Toledo district. The difficulty however of monitoring and estimating degradation should not dissuade one from trying to develop and adapt methodologies that allow us to estimate the effects of human and natural causes on forest.

There is definitely the need for monitoring of land use in Toledo through frequent mapping (at least annually) for forest change. It is also important to note, that for degradation to be reduced it is imperative, to keep track of degradation patterns, so as to pinpoint the events that affect more drastically forest structure and composition, and the availability of forest to provide environmental goods and services. A more robust analytical approach would be the modeling of the wide range of factors at both the community and farm/household scale that influence land uses and degradation patterns.

9.1.9 Important components for monitoring forest degradation

Monitoring of degradation, similarly to deforestation, is possible by making use of various scientific and traditional techniques which can be used in the detection of forest degradation and degraded forest. (IAP 2009). Monitoring is especially important for promoting sustainable land management activities, benefiting both forest dependent communities and climate change initiatives.

There is no single, agreed upon method to monitor forest degradation just as there is not one definition of what constitutes degradation. The choice of the approach for monitoring degradation depends on a number of factors such as; the cause and severity of degradation, availability of data, capacities, resources, and the limitations of the selected approach (Gofc-Gofd).

The components of monitoring to be most considered are based on literature review and guidelines for monitoring of degradation as recommended by the FAO and IPCC standards (IPCC 2003b; FAO 2011).

Monitoring objective

Monitoring should not be done without first recognizing the objective of wanting to monitor. For the purpose of Climate change one may be inclined to monitor change in Carbon stocks within forest (IPCC 2003). One may also monitor the reduction of a particular product or ecosystem service previously provided by forest within the area (FAO 2011).

Definition

The definition adopted or used to describe forest degradation may also hold implication when undertaking estimation and monitoring. There exist a diverse glossary of definitions ranging from ones placing emphasis on reduction in ecological integrity, reduction in ecosystems goods and services to others with primary focus on carbon emissions and enhancement in the framework of climate change mitigation and adaptation(IPCC 2003a).

Definition should also take into account, the local context (local policies, uses, traditions, etc.) and their effect on forest. They can be chosen based on parameters used for monitoring. In the framework of climate change, change, forest composition and structure are closely related to change in carbon stocks. However, in light of the high dependency of communities on forest, there might be other aspects like ecosystem services that could change the climate change approach and definition selected.

In this study, the parameter of forest used to detect degradation was the persistent decrease of canopy cover/forest density. An ecosystem state of degradation can be defined by the dominant floristic (tree) composition and stand structure expected for a given stand, based on the original forest.

The parameter/s or indicators used for monitoring

Based on the objective of monitoring, degradation can be tracked by changes in parameters of the forest, such as canopy cover, height and area, considering their respective thresholds in relation to what constitutes a forest.

When monitoring carbon emissions, the IPCC defines five (5) carbon pools to be measured and monitored; aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon. The carbon lost from forests and released to the atmosphere through the degradation process is commonly measured through forest field sampling and repeated forest inventories. Based on IPCC standards, changes should be calculated for each of the five forest carbon pools.

Using a gain-loss approach for estimating emissions, biomass losses can be accounted for with data on timber harvests, fuel wood removals, and transfers of live to the dead organic matter pool. Carbon stocks in each pool would be estimated both before and after degradation (e.g. a timber harvest), and the difference in carbon stocks in each pool calculated (GOLC-GOLD 2010).

Similarly for the monitoring of ecosystem services, changes within the structure and composition of a forest can cause degradation by the reduced providence of ecosystems services such as timber products, connectivity, soil fertility and even biodiversity of the area.

Based on the objective of this study, the parameter used to measure degradation was vegetation/canopy density, either through a persistent decrease of canopy cover/density, due to logging or by the generation of a non-structured forest caused by farming practices in the Toledo district. Degradation was calculated by analyzing pixels which experience a persistent reduction of density in time or pixels that experienced a cycle of density change, associated with Milpa farming practices. Intact forest were not used as reference point as it is believed that based on FAO 2011 that intact forest does not exist in the Toledo district.

Regenerating forest are classified, due to the lack of a definite structure and lack of canopy cover typical of the original forest, resulting in the reduction of the ability to supply goods and services to the people of Toledo, as would be expected from the original forest it replaced. For this purpose, vegetation cover (in percentage) change in each pixel was monitored in time using different dates of Landsat images. For each kind of degradation presented in this study, different patterns of vegetation cover was analyzed. To detect pixels where a sustained decrease in vegetation cover occurred, GIS tools where used to identify this trend, by selecting pixels where vegetation cover had followed the following pattern for 3 straight dates:

- Earlier date > Middle Date > Latter date (all of vegetation cover greater than 10%)

On the other hand, to detect regenerating forest through Milpa practices, vegetation cover (in percentage) in a given pixel presented the following pattern:

-Earlier date vegetation cover< 10%
-Middle date vegetation cover > 10%
-Latter date vegetation cover >10%

Scale at which monitoring has been carried out

The scale selected is based on the objective of monitoring and the extent of the area where monitoring will occur (FAO 2011).

*Local***:** monitoring is limited to a stand/s or site and may not require historical monitoring. It is useful when assessing effective corrective action at the local level.

*Spatial scale***:** Spatial scale relates to the size of the pixels within images and the extent in areas of images. Spatial scales are preferred when assessing and monitoring an entire forest management unit and over a landscape (e.g. district). The use of spatial scale analysis is necessary for national and international reporting and monitoring.

Technology used

Developing countries frequently lack consistent historical field data. And thus in assessing degradation of historical proportions, most developing countries is forced to rely strongly on remote sensing approaches mixed with updated field assessments.

Remote Sensing and Geographic Information System

Remote sensing technologies applied via the use of geography information systems, are increasingly used to monitor landscape change in many parts of the world. The availability of extensive and timely imagery from various satellite sensors and institution, both with a cost and free of monetary charge, has allowed us to estimate and monitor the extent of degradation(Rinku 2006).

For the purpose of monitoring degradation by structural change, such as caused by agricultural systems and logging at the landscape level, one may make use of Landsat imagery, which are currently available with reduced cost or free of charge, a resolution, ranging from 10-60 m and a minimum mapping unit of 0.5 to 5 ha adequate for monitoring forest degradation.

In this study Landsat images were succumbed to a Spectral Mixture Analysis (SMA). This mixture allows one to estimate the proportion of different land cover components within a pixel. (e.g. each pixel is analyzed based on percentage vegetation, shade, and bare soil therein)(Gofc-Gold 2010).

Remote sensing does not replace the need for good field data, and the combination of both methods provides better results than does either method alone.

Aerial photography

Aerial photographs are very useful in monitoring forest degradation because of their enhanced spatial resolution (pixel size can range from 5 to 50cm) LIDAR technologies (Light Detection and Ranging) can also be applied in airborne remote sensing, being very useful for campy height determination and thus an interesting tool when studying vegetation growth or regrowth. Based on studies that have used aerial photography, it has been considered as very useful due to its high level of accuracy and the requirement of little technology. However, due to its cost and the replacement of satellite imagery, aerial photography has been decreasingly used in the last years.

Ground estimation/ Field surveys

The lack of historical data and validation of remote sensing technologies depend greatly on ground estimation or field survey. It is also very valuable when collecting data not just on Carbon but also other ecosystem services. Based on the availability of resources, ground estimation can be used to collect data both at the local and national scale provided that persons collecting data are trained to do so in the most accurate way, without going into complex methods. A wealth of information can be acquired through the establishment of Permanent Sampling Plots (PSP) across countries.

Ground estimation can be limited by the lack of resources, time and inaccessibility to areas under study.

Ecosystem service valuation

The ecosystem approach takes into account the other values of forest not just limited to carbon. However due to the difficulties of monitoring certain services (e.g. integrity of forest), this approach may be very difficult and daunting, requiring the use of sometimes advanced technologies outside of the forest sector.

The different methodologies that already exist

Generally two methods can be used when analyzing forest degradation using remote sensing: the direct and indirect. Direct detection and monitoring of degradation focuses on forest canopy damage. The features enhanced and extracted from the satellite imagery are forest canopy gaps, small clearings that represent structural forest changes resulting from disturbance (FAO 2011).

Indirect approaches focus on the spatial distribution and change caused by human activities such as infrastructure (e.g. roads and population), which are used as determinants for newly degraded areas

The decision regarding which method to use will depend largely on the availability of existing data and resources to collect additional data. Estimating the impacts of logging on carbon stocks is more effective by considering the gain/loss approach. This approach could be used for all forms of biomass extraction (timber and fuel wood, legally and illegally extracted) and can produce more accurate and precise emission estimates cost effectively (GOLC-GOLD 2010).

Methods for reporting and monitoring in a climate change based approach must be in line with the IPCC Good Practice Guidance and can also take into account methods for monitoring carbon emission based on the recommendations of the Global Observation of Forest and Land Cover Dynamics guidelines.

Data analysis method

Data can be analyzed by the establishment of a reference state or a baseline (initial state), against which the changed situation can be compared. Though preferred, the unavailability of data on

primary forest or intact forest is not of outmost importance for monitoring. In this sense, sustainably managed forests for production could also serve as a reference state, even though they may lack some species, processes, functions or structures found in a primary forest.

In this study, primary forest was not used as a baseline, but rather the comparison analysis of persistent proportional variation of each pixel within the given study period.

Timeframe for monitoring degradation

Forest degradation may require frequent mapping, at least annually due to the dynamic nature of forest and rapid change in spatial signatures of degraded forest. Based on the monitoring approach especially for the spatial scale of monitoring, satellite data can make available consistent information collected globally. Information can, in turn, be analyzed in the same way for different points in time to derive better estimates of change.

Monitoring at the stand or site level, and based on the objective of the study, may require more frequent data collection considering the dynamic nature of forest.

Based on the objective of this study, monitoring of the drivers and extent of degradation caused by persistent density loss and regeneration caused by Milpa farming can be monitored on an annual basis or at an interval dependent on the availability of satellite images

Ground truthing

As mentioned above, the use of remote sensing ideally requires ground reference data (ground truthing). This data can be collected independently, based on the study or from data bases from relevant sectors or ministries of government. Close attention should be placed on forest cover prone to change or land cover that can be easily confused with others.

Constraints

The timeframe for monitoring degradation may be a constraint, considering the frequency of which it must be done. Monitoring on an annual or biannual basis may prove more beneficial, due to the change in the spatial signatures of degraded forests change when canopy gaps close based on the dynamic nature of forest (Gofc-Gold 2010).

Not all degradation processes can be monitored with high certainty using remote sensing data. Many direct activities that result in degradation, such as collection of fuel wood, affect only the understory and are undetectable through remote sensing analysis

The human-caused forest degradation signal can be confused with natural forest changes such as wind throws and seasonal changes. In an effort of reducing such a constraint this study only analyzed pixels with a persistent decrease in forest density, allowing us to eliminate factors such as natural disturbances and processes(Gofc-Gold 2010).

Lack of data bases, though prepared for other purpose such as timber and non-timber extraction may limit monitoring of forest degradation.

The cost of monitoring
The cost of monitoring forest degradation is determined by the method and technology employed. Cost may range from free to affordable to very expensive.

Drivers of degradation
Anthropogenic causes of forest degradation stem from a complex mixture of direct and underlying causes which should be considered when monitoring forest degradation. The effects of human activities can also be much more persistent and may causes a domino effect of one direct or underlying causes giving raise to many others(Geist & Lambin 2002; Lambin *et al.* 2003).

Activities geared at reduction of degradation should concentrate on anthropogenic causes which can be controlled by varying interventions. this does not place take away however the importance of monitoring human activities after natural disturbances since damaged forest are prone to extraction of product, by greater accessibility to damaged areas and other effects provoked by natural causes. The effects of Natural causes however, are less subjected to interventions by policies or management activities(Lambin *et al.* 2003).

The drivers of degradation can be monitored by using both qualitative and quantitative data. Data can be acquired from databases, records, interviews, workshops, surveys, secondary literature and if needed even in-depth study of groups of persons behind the cause (ethnography).

Persons involved in monitoring
Monitoring of forest degradation can be undertaken by all, providing the availability of adequate resources to do so. Governments especially, for the purposes of reporting on carbon emissions and based on management objective of national territories, may undertake monitoring activities to curb forest degradation.

At the local level, the involvement of local stakeholder, socio-political structures (town councils and Alcaldes), academia for the recording and reporting of forest use is vital when monitoring forest degradation. Reporting and recording of use at the local level allows for greater understanding of forest use, valued forest products, and even trends in product use. It is believed that by engaging local communities there is greater ownership on the forest resources felt by local stakeholders and greater involvement in management activities.

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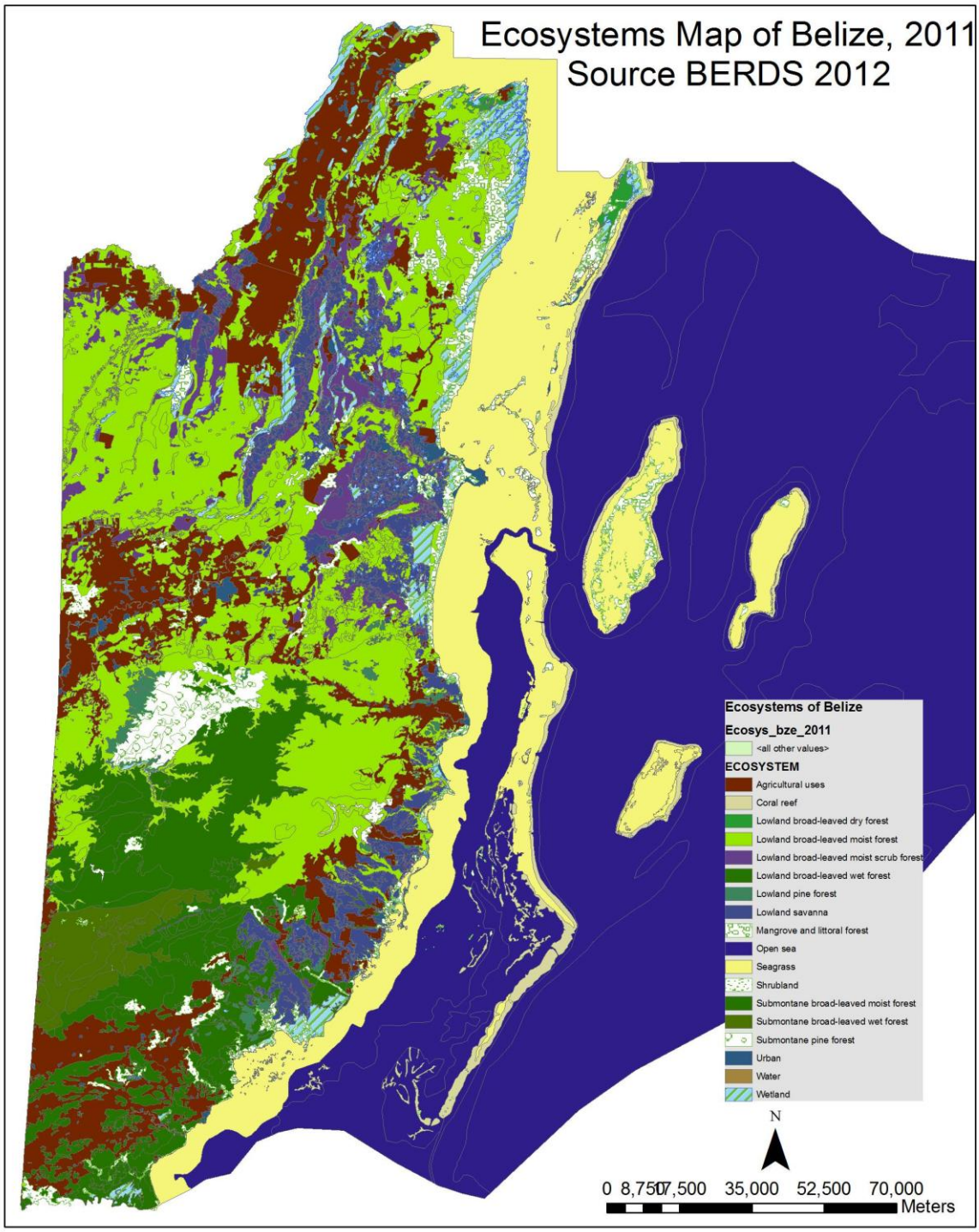
11 APPENDIX

Appendix 1. *Ecosystems map of Belize (BERDS 2012)*



Appendix 2: Organizational questionnaire of study

ORGANIZATION QUESTIONAIRE

This questionnaire is a tool in a scientific research being carried out by Mrs. Hannah St. Luce Martinez with the general objective of researching forest degradation in the Toledo district so as to promote sustainable forest management. This is a requirement by the Graduate school of CATIE for consideration of Masters in Science in Tropical forest and Biodiversity management.

The responses of this questionnaire will be considered confidential and at no point will names be released.

1. **General Information**

2. States which sector your organization belongs to: Government ___ NGO ___ Private ___ Community ___ other ___

3. Name of the organization _____

4. What is the overall function of your organization? _____

5. Knowledge with forest management in Belize: Very familiar ___ somewhat familiar ___ Not familiar ___

6. Level of involvement in forest management activities: Full ___ Partial ___ Limited___ None___

11. Direct Causes of Degradation

1. What do you understand by the term forest degradation*?* _____

2. Can you identify the top 3 activities which you consider as direct causes of Forest Degradation in the Toledo district?

    1. _____
    2. _____
    3. _____

3. Based on the 3 activities chosen which do you consider to be most negatively impacting on forest structure? _____

4. Why? _____

5. Are you aware of local uses of the forest in the Toledo district? And its frequency (Daily, Monthly, seasonally)

Local use	frequency	Amount extracted

6. What are the main products extracted from the forest for commercial use in Toledo?_____

Product	use	Amount extracted

111. Underlying causes of Forest Degradation

1. Please state the economical level most predominant in the Toledo district?

   Poor (Below minimum wage)_____ working class___ well provided _____

2. What are the main livelihoods of persons within Toledo?

   _____ _____

3. Do you consider the economic status of members of these communities an important factor in how forests are used and managed?

4. Should local communities play a role in forest management?

5. Should local and traditional knowledge be taken into consideration in management planning of forest use in Toledo?

6. What do you believe to be the role of local government in forest management?

7. Are you aware of any training received by members of your organization in forest management within the last 5 years?

8. Are you aware of training received by community members within the last 5 years in forest management?

9. What areas of training do you consider important to improving forest management?

    1.
    2.
    3.
    4.

10. Should women be involved in forest management no matter what the institution or community level?

11. Do you believe that local communities play a role to in Forest Management?

12. What would you recommended for improving local participation in forest management in Toledo?

13. What do you consider to be the 3 most important underlying causes of direct cause forest degradation in Toledo mentioned before?

Poverty_____ Culture_____ Educational standards_____ Poor institutional structures_____ Weak Laws_____ Negative political influence____

14. Please state why you have chosen the top three._____
    _____

_____
___

15. What are some of the strengths and weaknesses of land/forest management in Toledo?

Strengths_____ _____ _____

Weaknesses_____ _____ _____

16. Are you aware of the legal regulations governing forest management in Belize? Yes____ NO____

17. Do you believe that these legislation and regulations governing forest management are sufficient for promoting sustainable forest use/management?

18. What are some of the strengths or weaknesses of the permitting and licensing system for forest use?

Strengths _____

Weaknesses _____

24. What recommendation would you make for reducing forest degradation in Toledo?

1.

2.

3.

4

ASSESMENT OF NATURAL DISTURBANCES

1. Which of the following (within the last 10 years) do you consider as having a major impact on the forest in the Toledo district?

Hurricanes____ Fires ____ Floods_____ Drought_____

2. Why? _____

3. List some impacts observed to the forest In Toledo:

_____

Appendix 3: Community and local stakeholder questionnaire of study

Solutions for environment and development
Soluciones para el ambiente y desarrollo

COMMUNITY AND LOCAL STAKEHOLDER QUESTIONAIRE

This questionnaire is a tool in a scientific research being carried out by Mrs. Hannah St. Luce Martinez with the general objective of researching forest degradation in the Toledo district so as to promote sustainable forest management. This is a requirement by the Postgraduate school of CATIE for consideration of Masters in Science in Tropical forest and Biodiversity management.

The responses of this questionnaire will be considered confidential and at no point will names be released.

1. **General information**

Name: _____ (Optional)

1. Community _____
2. Dominant ethnicity in Community_____
3. Population size _____
4. What is the distance to the nearest forest from your community? _____
5. What does the forest of Toledo mean to you and your community?

6. List the values of the forest most important to you?

Value	Frequency used	By whom

7. What are the local uses of the forest in the Toledo district? And its frequency (Daily, Monthly, seasonally)

Local use	frequency

8. Does the forest near the community provide resource used domestically?

9. Does the forest provide a steady income for your home and other members of the community?

10. What percentage of members within you community would you state as being dependent on the forest to maintain their livelihoods?

11. What are the main Non timber forest products and if possible species of tree extracted from the forest?

Non Timber Product	use	Distance into the forest to attain product (Near, somewhat distant, Very Distant)	Amount extracted	Percentage of community who carry out this activity

12 . What are the main timber products and if possible species extracted from the forest for commercial use?

Timber Product	use	Distance into the forest to attain product (Near, somewhat distant, Very Distant)	Amount extracted	Percentage of community who carry out this activity

1V. Direct Causes of forest degradation

1. What do you understand by the term *forest degradation?*_____

2. Can you identify the top 3 activities which you consider as direct causes of Forest Degradation in the Toledo district?

_____

_____

_____

3. Based on the 3 activities chosen which do you consider to be most negatively impacting?
_____

4. What changes have you noticed of the forest within the last 10 years?

5. What do you consider to be the main cause of this change? _____

6. Have you noticed changes in the availability of forest products in the last 10 years?

7. Have you noticed changes in the distance needed to travel to acquire products used?

V. UNDERLYING CAUSES OF FOREST DEGRADATION

1. What are the main job employments of members of your community?

2. Select the general economical level of your community using the following range?

poor_____ working class___ well provided _____

3. Do you consider the economic status of members of your community an important factor in how forests are used and managed?

4. Within the last year have members of you community received training in forest management?

1.
2.
3.
4.

5. What areas of training do you consider important to forest management?

1. _____
2. _____
3. _____

6. Are women within your community involved in forest management/use?

7. Do the women in your community take part in trainings?

8. Should women play a role in Forest Management?

9. Does your community play a role in Forest Management in your community?

10. What do you believe to be the role of communities in Forest Management?

11. What do you consider to be the role of local habits and traditional knowledge in forest use/management?

12. Would you consider members of your community as being capable of sustainable forest management?

13. In your opinion, what would be needed or should be improved in order to reduce forest degradation?

14. What do you consider to be the 3 most important underlying causes of the direct causes of forest degradation in Toledo?

Poverty_____ Culture_____ Educational standards_____ Poor institutional Capacity _____ Weak Laws_____ Negative political influence____

15. Please rank the 3 most important underlying causes of each direct cause of forest degradation selected

_____

_____

_____

16. What do you consider to be your role in Forest Management in Toledo?

17. What role do you believe should be undertaken by local government in forest management?

18. Are you aware of the regulations and permits required as it relates to forest use/ management in Belize?

19. Do you believe that the current legislation and regulations governing forest management are sufficient for promoting sustainable forest management?

20. What recommendation would you make for reducing forest degradation in Toledo?

1.

2.

3.

4

V1. ASSESMENT OF NATURAL DISTURBANCES

Which of the following (within the last 10 years) do you consider as having a major impact on the forest in the Toledo district?

Hurricanes____ Fires ____ Floods_____ Drought_____

Why? _____

List some impacts observed to the forest In Toledo: _____

Appendix 4. List of Participant for definitions workshop

Objective: Definition of forest terms	
Date	27th of February
Venue	MNRE
Time	01:30
Participants	
List of Participants	Organization
Jan Meerman	BTFS
Ramon Pachecco	Program for Belize
Clifford Martinez Jr	Ministry of Agriculture
Wilber Sabido	Chief Forest Officer
Oswaldo Sabido	Consultant/Forester
Tanya Santos Neal	CATIE/Forest Department
Rafael Lima	Land Information Center, MNRE
Elam Torres	Land Information Center, MNRE
Edilberto Romero	Exc. Program for Belize
Colin Young	National Protected Areas Secretariat
Judene Tingling	Forest Officer
Philip Tate	Ministry of Agriculture and Fisheries
Hannah St.Luce Martinez	CATIE
Percival Cho	Independent reseacher (participated via email)
Elma Kay	University of Belize (participated via email)