'YES IN MY BACKYARD'

Market based mechanisms for forest conservation and climate change mitigation in La Primavera, México

Arturo Balderas Torres

UNIVERSITY OF TWENTE.

‘YES IN MY BACKYARD’
MARKET BASED MECHANISMS FOR FOREST CONSERVATION AND CLIMATE CHANGE MITIGATION IN LA PRIMAVERA, MÉXICO

DISSERTATION

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Colofon

Cover Photo: View of the limit between La Primavera Biosphere Reserve and the metropolitan area of Guadalajara in 2009 by Arturo Balderas Torres.
Backcover Photo: ‘Don Cástulo’, the largest tree found in La Primavera during fieldwork; it was catalogued as a ‘Majestic Tree’ by SEMARNAT, CONAFOR and La Primavera Executive Office in 2010, photo by Arturo Balderas Torres.

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List of Abbreviations.

ALICEA: Asociacion Latinoamericana de Investigación y Capacitación en Educación Ambiental, A.C.
AMBIO: Cooperativa AMBIO, environmental NGO coordinating the project Scolel Té in the voluntary carbon market.
C.C.: Canopy cover.
C.I.: Confidence interval.
CB: Co-benefit, ancillary benefit.
CCMSS: Consejo Civil Mexicano para la Silvicultura Sostenible.
CDM: Clean Development Mechanism.
CER: Certified Emission Reduction.
CIESAS: Centro de Investigacion y Estudios Superiores en Antropología Social.
CIGA-UNAM: Centro de Investigación en Geografía Ambiental-Universidad Nacional Autónoma de México.
CM or CE: choice modelling or choice experiment.
CO_2, CO_{2eq}: carbon dioxide/ carbon dioxide equivalent.
COLMEX: Colegio de México.
CONAFOR: Mexican National Forest Comission (Comisión Nacional Forestal).
COP: Conference of the Parties.
CP: Producer surplus.
CS: Consumer surplus.
CV: Contingent valuation technique.
ECOSUR: Colegio de la Frontera Sur.
ERU: Emission Reduction Unit.
ES: Environmental service.
EUETS: European Union Emission Trading Scheme.
GHG: Greenhouse gas emission.
INE: Instituto Nacional de Ecología/National Institute of Ecology
IPCC: Intergovernmental Panel on Climate Change
ITESO: Instituto Tecnológico y de Estudios Superiores de Occidente.
KP: Kyoto Protocol.
LULUCF: Land use, land use change and forestry.
MAG: Metropolitan Area of Guadalajara.
Monetary Figures ($): all monetary figures are expressed in US dollars, the considered exchange rates to Mexican pesos are indicated.
NGO: Non-Governmental Organisation.
PES: Payment for environmental services.
PROEPA: Procuraduria Estatal de Protección al Ambiente/ State Attorney General of Environmental Protection of Jalisco.
REDD+: Reduced emissions from deforestation and forest degradation in developing countries.
REL: reference emission level.
RL: reference level.

SBSTA: Subsidiary Body for Scientific and Technological Advice
SEDER: Secretaria de Desarrollo Rural del Estado de Jalisco/ Mnistry of Rural Development of Jalisco.
SEMADES: Secretaria de Medio Ambiente y Desarrollo Sustentable del Estado de Jalisco/ Ministry of Environment and Sustainable Development of Jalisco.
SERMARNAT: Mexican Federal Ministry of Environment (Secretaria de Medio Ambiente y Recursos Naturales).
TC: Transaction cost.
TSD-CSTM: Technology for Sustainable Development Group- Twente Centre for Studies in Technology and Sustainable Development.
UNFCCC: United Nations Framework Convention on Climate Change.
WTA: Willingness to accept.
WTP: Willingness to pay.

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1. Introduction

The central objective of this thesis is to evaluate the potential role of local markets as a means of providing incentives for increased provision of forest carbon services, in contrast to international market mechanisms of the sort that are being developed in the context of the United Nations Framework Convention on Climate Change (UNFCCC). For countries such as México, such schemes may have various advantages. The feasibility of local carbon markets relates to the possibilities for engaging local providers and local users of these services. To explore their potential role it is therefore necessary first, to estimate the potential for production of carbon services in forests, secondly to assess the willingness of landowners to provide them, and thirdly the willingness of users to pay for them. These issues are studied in the central chapters of this thesis, using a case study of the dynamics between La Primavera forest and the nearby Guadalajara city in México. This information provides the necessary input for the design of an appropriate institutional framework to value forest carbon services. Most of this material has either been published already in academic journals or has been submitted for publication.

The thesis is based on the notion that with appropriate management, ecosystems provide a wide range of services and benefits that help to satisfy human needs (de Groot, 1992; de Groot et al., 2002). These ecosystem or environmental services include functions of regulation, habitat, production and information values (de Groot et al., 2002) encompassing benefits such as protection of water catchments and biodiversity habitat, sites for recreation and climate change mitigation (Canadell and Raupach, 2008). Interest in forest management for climate change mitigation has grown since it has been shown to be a cost efficient way of achieving reductions in carbon dioxide emissions (CO_2) and carbon sequestration (Stern, 2006; Brown et al., 1997; Dixon et al., 1993; Strassburg et al., 2009; Canadell and Raupach, 2008). Forests remove atmospheric CO_2 and store it in different reservoirs (i.e. biomass, dead organic matter and soil) (IPCC, 2006), thus contributing to the reduction of net emissions of greenhouse gases (GHG) and their atmospheric concentrations. However, many of the environmental benefits delivered by forests and other ecosystems are not provided at optimum levels since they are not captured in common economic decisions and transactions and are regarded as public goods (i.e. non-rival, non-excludable). Thus usually landowners or forest-holders do not consider these benefits in decision-making. This leads to under-provision of the environmental services (ES) since landowners opt for other more profitable activities or land uses, hence generating an ‘external’ effect in the form of a net loss of social benefits (Landell-Mills and Porras, 2002; Pagiola and Platais, 2007).

There has been increasing interest in setting up mechanisms by which goods and services derived from natural ecosystems can be recognized in market-based systems (Landell-Mills and Porras, 2002). This is to overcome the well-known problems of externalities, market failure and free-riding which occur when natural services are regarded as public goods (Pigou, 1932; Bator, 1958; Samuelson, 1954; Cornes and Sandler, 1996; Stern, 2006). Market theory postulates that markets fail to provide optimal levels of ES because the prices of goods and services exchanged in the existing markets do not usually include the social values that the environment provides (e.g. Landell-Mills and Porras, 2002). One of the options to correct this failure is to directly integrate the value of the externality into the prices of goods and services, *via* taxes or subsidies or to develop market mechanisms (e.g. Perman et al., 2003). It is important to mention, however, that other market and public failures may exist, which could interfere with the provision of ESs[1]. According to economic theory, efficiency gains arise in markets because actors, in this case, users and providers of the environmental services, can meet and bargain socially optimal outcomes (Coase, 1960). In this context, the 'market' is understood as the 'space' created by an institutional framework within which these providers and users meet to set agreements for the provision and valuation of the environmental services. These market-based schemes are designed to create incentives for landowners to manage their land optimally to provide services such as water, carbon sequestration and biodiversity conservation, while ideally transferring the cost to the polluters or users of these services (*e.g.* Landell-Mills and Porras, 2002; Wunder, 2005; Pagiola and Platais, 2007; Muñoz Piña et al., 2008, Pagiola et al., 2002).

Arrangements between producers and users for the valuation of forest services can be made at a variety of scales (Landell-Mills and Porras 2002). For instance, in the case of hydrological services, valuation is typically at the watershed level where producers and users coexist. Such policies can be implemented in the form of programs of Payments for Environmental Services (PES) (*e.g.* Pagiola et al., 2002). Wunder (2005) initially defined them as voluntary transactions, to value defined and specific services, between at least one buyer and one provider, where the provider secures the service provision (conditionality); thus typically in PES landowners or communities receive a yearly flat payment per hectare for the conservation of their forests provided they comply with the program requirements. Most of the time these requirements refer to the maintenance of certain minimum levels of environmental conservation (e.g. canopy cover) or the implementation of specific management practices favouring the provision of the services. In the case of climate change mitigation services, the scale of these schemes can be global, since reductions of greenhouse gases emissions or carbon sequestration are equivalent all over the world (Pagiola et al., 2002); examples of these global schemes are the carbon markets for reforestation and afforestation projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol, the voluntary carbon markets and those market-based mechanisms that might operate as part of the international programme to reduce emissions from deforestation and forest degradation in developing countries (REDD+) (UNFCCC, 2012a). In the context of carbon markets, specific activities and projects are developed to reduce greenhouse gas emissions and increase carbon removals. The benefits for climate change mitigation are accounted as the extra or additional carbon benefits (reduced emissions or increased removals by sinks) in comparison to a baseline (i.e. what would have happened in the absence of the intervention). The project developer can register and certify the project according to approved methodologies under the United Nations Framework Convention on Climate Change (UNFCCC) or voluntary certification organizations (e.g. Voluntary Carbon Standard,

[1] e.g. market failures: incomplete information, strategic behaviour, incomplete property rights (Perman et al., 2003); public failures: incomplete information, uncertainty on long term action, poor implementation of the regulatory framework/strategic behaviour (Lévêque, 1999).

Plan Vivo) and ‘sell’ or trade the certified or voluntary emissions reductions, offsets or carbon credits in the related markets.

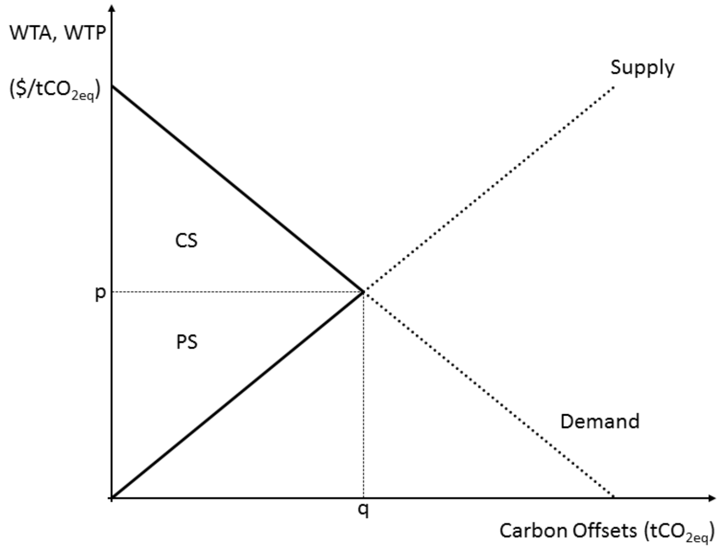
In order to realize the value of forest climate services, predictable and accessible positive incentives are essential (UN, 2010). International agreements under the United Nations Framework Convention on Climate Change (UNFCCC) have focused on the development of actions to control greenhouse gas emissions at lowest possible cost (UNFCCC, 1992; UNFCCC, 1997). One advantage of market-mechanisms is that they help to develop cost-effective mitigation options (Aldy et al., 2003). Market-based mechanisms need to stimulate the demand and valuation of the environmental goods or services of interest at specific levels that ensure their provision. This is achieved by motivating the potential providers to participate in the schemes; it is expected that the value of the incentives should at least match the associated costs of participation and implementation. However, existing global carbon markets have not stimulated widespread development of forestry-based actions. There are higher hopes that actions under REDD+ will help to reduce forest-related carbon emissions in developing countries but the rules on how this will be done have not yet been completely established.

It is in this context that this research is framed, with a view to exploring the potential for local market mechanisms for the valuation of forest carbon services, rather than global markets, and to explore their potential to contribute to sustainable development. Specifically in the context of México, exploring the potential for local markets targeting the forest sector can aid to define the contribution that these policies can make to realise local environmental targets set as part of the implementation of REDD+ and local climate policy.

1.1. Research Framework and Research Questions

The imbalance between emissions and removals by sinks produces the accumulation of GHG in the atmosphere thus contributing to climate change. Thus climate change mitigation efforts aim to reduce emissions and increase removals. In carbon markets the potential buyers of carbon credits or offsets are those who generate GHG emissions and cannot undertake other, cheaper mitigation actions in order to fulfil their environmental goals. In the case of the compliance carbon markets derived from the Kyoto Protocol (KP), Annex I, developed countries listed in the Annex B of the KP can buy carbon credits from the CDM and/or use the other flexible market-based mechanisms of KP (i.e. emissions trading and joint implementation projects) to comply with their emissions reduction targets (5% of emissions during 2008-2012 in reference to 1990 levels) (UNFCCC, 1998). In voluntary markets, buyers without legal obligation to reduce emissions can decide to undertake climate change mitigation actions; companies and individuals are buying carbon credits or offsets from the voluntary market in order to comply with internal objectives such as environmental and social responsibility, green marketing or as a pre-compliance phase for new policies (Peters-Stanley and Hamilton, 2012).

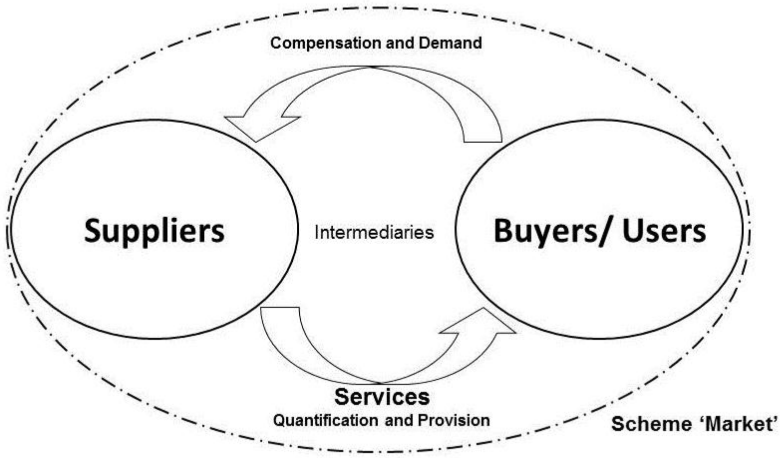
Figure 1.1 Typical supply-demand diagram to show the clearance price in market-based mechanisms. The lines indicate the WTP (Demand) and WTA (Supply) for carbon offsets.



According to economic theory, the exchange between providers and users in markets will occur as long as the willingness to pay (WTP) of the users (demand), is higher than the costs of provision of the services and the willingness to provide the services by the suppliers (WTA) (supply). The WTP is used in this context as a proxy for the benefits received by buyers. Figure 1.1 refers in this case to the provision of forestry carbon services measured as the level of reduced emissions and/or increased carbon removals that can be obtained at a given cost or carbon price. The price given at the equilibrium between marginal demand and supply in Figure 1.1 would be sufficient to buy ‘q’ credits or offsets at price ‘p’. Given the supply costs expressing the WTA by providers in the diagram, no mitigation actions would be expected beyond point ‘q’ since potential payments that could be made to the suppliers would be lower than the costs (WTA>WTP). The aggregated benefit for the buyers (or savings in comparison with their maximum WTP) is identified as the consumer surplus (CS), which is the triangle above the price line, the vertical axis and the line for the demand. The benefits for the providers are given by the producer surplus (PS) (difference between what they get paid at the market price and the cost of provision). The WTP captures the valuation that users/buyers may give to the offsets, not only in terms of mitigation of climate change but also related to other co-benefits which they value. On the other hand the WTA might also capture other benefits received by the suppliers associated with the implementation of the mitigation activity. In both cases, buyers and suppliers may value the participation in market-based mechanisms for environmental services considering both cash incentives and other co-benefits, which may be weighted and perceived according to their individual contexts (e.g. Daw et al., 2011). According to standard market theory, the global carbon market can offer opportunities to reduce the cost of climate change mitigation because least cost options could potentially be developed in areas with lower abatement costs (developing countries). However, it is expected that market-based schemes linking producers more closely to the potential demand (consumer) should offer opportunities for greater efficiency and more sustainable financing for the effective maintenance of environmental services (Pagiola et al., 2002). The approach adopted in this research investigates the possibility of valuing forest carbon services through domestic carbon markets built on local demand, while exploring the potential for local sustainable development. For this, the thesis uses a region in the State of Jalisco in México as a case study.

Figure 1.2 provides a simplified scheme of the main elements in a potential market-based mechanism showing the main research areas included in this study. The first element relates to the supply of the forest carbon services and is divided in two areas: the quantification of services in forests and the willingness of landowners, communities and forest holders to adopt practices to provide the services. The second main element refers to the valuation of these environmental services by users and potential buyers of carbon offsets and the potential for participation. The third element refers to the characteristics that a market scheme could include in order to link the suppliers and buyers under an institutional framework.

Figure 1.2 General scheme describing the different elements of market-based mechanisms for the valuation of forest carbon services included in the research.



In market-based schemes there are other actors interacting besides the providers and the buyers/users. One important group corresponds to the intermediaries or project developers. Sometimes they act as 'umbrella' organizations to group either suppliers and/or buyers and facilitate the implementation of the activities (e.g. Black-Solís, 2003). In national PES programs the intermediaries are usually the national governments or semi-autonomous public agencies as in the case of the Mexican or Costa Rican programs (e.g. Muñoz Piña et al., 2008; Pagiola, 2008). At other times intermediaries act as brokers aiming to get financial returns, since in carbon markets it is possible to buy and sell the credits. Another important group of actors includes academia, research centres, specific environmental governmental and international agencies and consultants generating information related to the provision and use of the services. The final group of actors includes the international bodies (e.g. UNFCCC), governmental offices and independent organizations shaping the market's institutional framework. The role of these actors can extend from validation and certification of projects under certain standards, to the enforcement of contracts between the participants in the market. Typically the flow of services goes from the conserved ecosystems in rural areas to the 'users', but without the insertion of some kind of institution in this flow, compensation does not take place. This research aims to explore the possibility of creating local carbon markets to fulfil this institutional need. The main research question thus becomes:

What is the potential for local carbon markets targeting forest carbon services in developing countries?

In order to answer the research question and evaluate the potential for local markets targeting forest carbon services, different elements associated to the quantification, supply, demand and potential institutional framework of these schemes need to be investigated:

1. What is the physical/biological potential for production of carbon services in forests?
2. Are landowners and communities willing to adopt practices to provide them?
3. How do citizens, as users of forest carbon services, value them?
4. What is the potential for a local market for forests carbon services and how could it interact with international efforts to mitigate climate change (e.g. global carbon markets, REDD+)?
5. What would be the potential contribution of these local mechanisms for development and what would be the implications for local climate policy?

It can be stated that in strict economic terms, a first condition for a market-based mechanism in which providers and users successfully reach an agreement to increase the provision of environmental services, is that the WTP by users is higher than the WTA of the providers. If there are favourable prospects in this regard, then it would be possible to elucidate how the scheme could be designed to favour participation. Local schemes could then be compared with the prevalent conditions in existing (global) carbon markets. It will also be possible to compare the cost of mitigation at given levels of biophysical potential as regards the provision of services in specific ecosystems; to evaluate the potential contribution of activities undertaken in the forestry sector to the design and implementation of environmental and climate policy; and to contrast the potential contribution that the valuation of natural capital, through the valuation of the environmental services, may represent for local development. In order to approach these questions, this research develops a case study in which the flow of environmental services generated in the Biosphere Reserve of La Primavera is estimated and its valuation by the population of the city of Guadalajara in Jalisco, México is assessed.

1.2. Case Study: Guadalajara and La Primavera Biosphere Reserve in Jalisco, México

México is a developing country with a high degree of urbanization and industrial activity and with a long standing policy on PES (Muñoz Piña et al., 2008). It is the 11th largest emitter of GHGs in the world (Vance, 2012). In 2008 México was one of the first countries to express a voluntary commitment to reduce emissions (Adam, 2008). This commitment has been formally registered under the UNFCCC and registered in the recently enacted General Law on Climate Change in México (LGCC) (SEMARNAT, 2012a). The objective indicates that México will have reduced its GHG emissions by 30% in 2020 (UNFCCC, 2011a), and 50% by 2050 (SEMARNAT, 2012a), with a substantial contribution from the forestry sector and market-based mechanisms (PECC, 2008; CONAFOR, 2010). The development of local markets for the valuation and provision of environmental services of forests is established as one of the strategies of the national government for 2007-2012, this policy is contained in the National

Development Plan, Axis 4, Strategy 3.3 (Presidencia, 2007). Considering the future implementation of REDD+ and the impulse that local voluntary carbon markets may have in México (CONAFOR, 2010), the role that forestry-based carbon mitigation activities will play in domestic climate policy will depend on how ambitious the specific sectorial targets are (they have still to be set) and how the rules for local carbon accounting and across different markets will be defined (i.e. global, compliance, voluntary and local carbon markets).

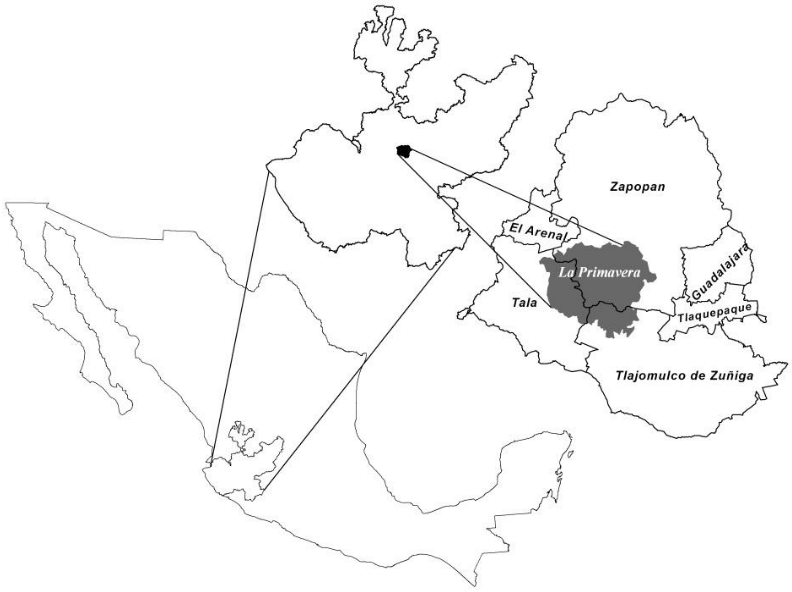
In 2003 the Mexican government, through the National Forest Commission (CONAFOR), created a PES program that today is one of the largest in the world. At present it is centralised, but the plan is that it will gradually be decentralized (Presidencia, 2007). There are also a number of PES programs financed by state level governments, such as Pro-Bosque in the State of México (State of México, 2011). Several critical steps need to be undertaken to decentralise and extend these programs. Implementation of PES programs that link directly to users have recently begun (e.g. a program using Concurrent Funds began in 2008 (Graf-Montero and Bauche-Petersen n.d.). In these programs local users of ES commit to pay the producers a PES for up to 15 years. The agreements are made directly between the local users and providers; in this scheme the federal government can make a contribution to match that of the local users. The fund is used to pay specific providers of ES (communities or landowners); however, the program is not yet implemented widely. In addition there are a number of carbon capture projects in the voluntary market, including Scolel-te and Neutralizate (ICCC, 2007). Clearly it will be important to establish the role that these activities may have in the forest-based strategies for climate change mitigation to be adopted at the national level.

In order to develop local markets for forest carbon services, one of the key questions to be answered is if the environmental valuation by the economy and society of an emerging country such as México is enough to finance the provision of these services. In order to address the research question the case of the Natural Protected Area “La Primavera” and the metropolitan area of Guadalajara is used as a case study (Figure 1.3)

This case was chosen because it offers a good example of a clearly identifiable natural area providing different goods and services to a particular group of users. La Primavera is an oak-pine forest located in the western part of México. It has 30,500 hectares and was declared a natural park back in 1980 (CONANP, 2000) and a Biosphere Reserve of the Man and the Biosphere Program in 2006 (UNESCO, 2011); it is located just next to the metropolitan area of Guadalajara which is the second largest city in the country, with 4.4 million habitants (INEGI, 2011a).

La Primavera offers several environmental services to Guadalajara, which include those related to air quality, hydrological, aesthetic and carbon services. Besides the environmental services provided, La Primavera also represents a risk to Guadalajara’s air quality in the case of forest fires. The ash and dust generated during one big fire in 2005 blanketed the city and heavily impacted normal economic and social life (El Universal, 2005). Fires are the main threat to habitat conservation and forest loss within the Reserve’s polygon. Land use change inside La Primavera is relatively controlled due to legal protection, however, some landowners are trying to promote land use changes due to lack of alternatives for local development.

Figure 1.3 Study Area, presenting the location of the State of Jalisco within México and the municipalities where La Primavera and the metropolitan area of Guadalajara are located.



However, urban pressure and land use change are isolating La Primavera and closing natural, but currently unprotected, biological corridors for wildlife outside the Biosphere Reserve. These pressures result in carbon emissions and threats to habitat conservation. Using this area of México as a case study can also provide insights to evaluate the potential of local market mechanisms for forest carbon services in terms of conservation and enhancement of biological corridors. Cougars (*Puma concolor*) are the top predator in La Primavera; however, biological corridors are needed to maintain a long term viable population, given the home range area required by pumas (e.g. Lindstedt et al., 1986; Beier, 1993). There has not yet been a formal assessment of the magnitude of carbon services provided by La Primavera, nor of the local valuation of these services by the habitants of Guadalajara. The specific objective of this research is to contribute to the quantification of these benefits and their valuation, and to determine the potential role that market-based mechanisms targeting the forestry sector may play in climate change mitigation and local environmental and climate policies.

1.3. Outline of the Thesis

The remaining part of this Chapter describes the general outline and rationale followed in each of the Chapters as a way of demonstrating the integrated nature of the research. Chapter 2 presents the basic background of market mechanisms and the gaps in knowledge that help to define specific research questions; this is followed by Chapter 3 describing the methodological approach adopted. Chapters 4 to 9 present the research findings for the quantification, demand, supply and the institutional framework for the valuation of forest carbon services which have been published or submitted to academic journals as individual articles; Chapter 10 concludes by integrating the principal insights found throughout the research and revisits the research questions and gaps in knowledge.

1.3.1. Theoretical Framework and Gaps in Knowledge (Chapter 2)

Chapter 2 presents the literature review on different topics covered by the research including the theory of market-based mechanisms for environmental valuation; factors affecting the valuation and demand for forest carbon services in carbon markets; the potential to integrate supply of such services into local development; and the diagnosis of the challenges for the valuation of these services using market-based mechanisms in the context of REDD+, particularly in México. The first section of this chapter describes the background associated with market-based mechanisms for the valuation of environmental services describing briefly the characteristics and differences of emissions trading, personal carbon trading, PES schemes and the voluntary carbon market. This is followed by a description of the difficulties that the valuation of forest carbon services face in existing markets stemming from the UNFCCC. The contribution of local market schemes for forest carbon services to sustainable development is discussed in the light of the livelihood approach to development (Carney, 1998) and the potential to reach a sustainable rate of emissions at the local level. Finally, the gaps in knowledge and specific research questions are formulated in the context of México, based on the findings of a participatory workshop undertaken in the study area in February 2009. In this workshop, different stakeholders associated with the management of natural resources in México, and particularly from Jalisco, participated in the identification of the causes of deforestation and forest degradation and the informational requirements for the development of local market-based strategies for forest carbon services. The final part of the chapter presents the discussions and conclusions based on the findings of the workshop along with the specific research questions and gaps in knowledge identified.

1.3.2. Methods (Chapter 3)

Chapter 3 presents a general overview of the methodological approach adopted to address the research questions and the key gaps in knowledge identified in Chapters 1 and 2. Chapters 4 to 9 include specific sections on the methodologies followed in the development of the research topics related to the quantification, supply, demand and creation of the institutional framework for market-based mechanisms for forest carbon services. Chapter 3 explains how they interrelate with each other and allow development of a coherent body of research. The main approaches to assess the potential and implications of local markets, which are described in Chapter 2, rely on the comparison of the WTP and WTA for local mitigation actions, the potential contribution to local development from a livelihoods approach and to a sustainable local balance of emissions and removals by sinks.

1.3.3. Quantification of Forest Carbon Services in Oak-Pine Forests (Chapters 4 and 5)

Chapters 4 and 5 present results on quantification of forest carbon services in the study area. Chapter 4 presents the results of a forest inventory undertaken in La Primavera during the summer of 2009 which are used to estimate carbon services in La Primavera based on content in arboreal biomass, potential carbon removals (i.e. enhancements from forest conservation and potential for carbon sequestration in non-forest area as grasslands and cropland), and potential reduced emissions. The information from 103 measurement plots of the forest inventory is used in combination with published allometric equations and growth functions for oaks and pines developed in México (Návar, 2009; Merlin-Bermudes, 2005; Návar-Cháidez, 2010). These permit to estimation of biomass and carbon in trees. By the aggregation of carbon content of individual trees in each plot, carbon estimates per hectare are obtained. The inventory was stratified by canopy cover in order to capture the heterogeneity of the conditions existing in the forest. This corresponds to a mix of Tier 2 and Tier 3 level approaches under the methodologies of the Intergovernmental Panel on Climate Change (IPCC) for estimating carbon stocks and stock changes (IPCC, 2003; IPCC, 2006). The estimates of carbon content are used in combination with a mid-resolution Landsat image to produce carbon figures for the Biosphere Reserve. Potential for reduced emissions from deforestation and forest degradation are estimated as function of the baseline level that could be adopted as part of national or sub-national REDD+ projects. Although the carbon estimates do not include all the carbon pools (i.e. dead wood, litter and carbon in soils), and an historical analysis of land use changes is not made to estimate the emissions from forest fires, deforestation or degradation, results presented provide a first conservative estimate of the local potential carbon services for the oak-pine forests in the study area.

Based on the results of the forest inventory, Chapter 5 analyses an alternative option to generate carbon estimates for trees in forests which may be faster and accurate; with a reduction in fieldwork effort. Although this data is not strictly necessary for the assessment of the potential of local markets, it supports the aims of the thesis by suggesting a methodology for forest inventory that might reduce transaction costs in the measurement and quantification of forest carbon services (in local markets as in any other markets). The potential to use basal area figures in order to predict carbon content using per hectare figures is explored. Basal area is a measure used in forestry to account for the level of stock in a forest; it represents the summation of the transversal area of all the tree trunks in a hectare measured at the standard height of 1.3 m. The literature has in general assumed that the relationship between basal area and biomass in trees, or carbon, is linear. Based on the analysis of the mathematical expressions of different specifications for allometric equations (these equations are used to obtain the weight of a tree as function of the size of its trunk), the relationship between basal area and carbon content is explored. Results indicate that best predictions are obtained when the relationship between basal area and carbon is regarded as non-linear. These insights can help to reduce the effort and cost of generating figures for carbon content in forests, since there are visual methods to estimate basal area in forests which do not require the individual measurement of trees. These are based on geometric principles and give values consistent to those obtained by the measurement of trees in standard inventory plots (e.g. Grosenbaugh, 1952; Piqué et al., 2011).

1.3.4. Valuation of Forest Carbon Services by Users (Chapters 6 and 7)

The valuation and potential demand for forest carbon services are presented in Chapters 6 and 7. Non-market techniques for environmental valuation were selected since there is at present no mature and widespread carbon market in México; and PES programs have not been decentralized. The choice experiment or choice modelling technique (e.g. Hoyos, 2010) was selected to evaluate how the location and cost of a project enhancing carbon services affected the valuation of these environmental services by the general public. This technique permits the estimation of the WTP for carbon offsets and requires the application of surveys in order to estimate the environmental values. The valuation exercise consisted of presenting to the participants theoretical different options for purchasing carbon offsets from forestry projects, varying in cost, the number of offsets to be purchased and location of the project. Carbon offsets from La Primavera were presented in competition with projects developed in alternative Biosphere Reserves: La Michilía in the State of Durango and El Cielo in Tamaulipas. It was proposed that participation was voluntary and the project was coordinated by a non-governmental organization (NGO), similar to the situation prevalent in the incipient voluntary carbon market. Chapter 6 presents the results of the experiment as it was undertaken in the metropolitan area of Guadalajara in order to compare how the survey application mode and the socio-economic profile of respondents affected environmental valuation. The surveys were applied in person through market-stall sessions (MacMillan et al., 2002) where the researcher had the opportunity to enter into dialogue with the participants in the study (typically in groups up to 8 to 12 persons). Two alternative on-line methods were used (i.e. snowball technique and through a hired market research company with a database of citizens' email addresses). The results arising from the three sampling methods are discussed. As expected in general, results show a preference for local mitigation projects in La Primavera, however, trade-offs are made in terms of global and local benefits. Furthermore the use of the different sampling techniques permitted access to different sectors of the society, which helped to identify specific determinants of environmental valuation (e.g. sense of responsibility over own GHG emissions, previous knowledge of personal carbon emissions, and marked differences in income).

The results presented in Chapter 6 are for the city of Guadalajara, and as expected show a preference for the local Biosphere Reserve of La Primavera. However, in order to test the consistency of the choices and evaluate whether the results were influenced by the design of the instrument, the same survey was applied using the market research company, to citizens with similar socio-economic profile from the States of Durango and Tamaulipas, other population centres outside the metropolitan area of Guadalajara in Jalisco, and México City. Thus four samples were obtained. In three of them the survey asked the participants to buy carbon offsets from local projects in competition with distant options to mitigate climate change (Durango, Jalisco and Tamaulipas), while for the fourth sample there were no local offsets to choose from (México City). Standard methods to assess the consistency of results across samples based on the benefit transfer technique were used to compare the environmental values from the four samples (e.g. Rolfe and Bennett, 2006; Poe et al., 2005; Krinsky and Robb, 1986). Results show a consistently higher valuation and preference for local projects for the development of forestry-based mitigation options, which is reflected in a higher WTP for carbon. When no local options were offered, participants presented a lower WTP for carbon, indicating a search for cost-efficient mitigation options. However, when asked, these participants indicated they had preferred the development of this type of projects in alternative locations closer to their residences revealing a ‘yes in my back yard’ effect. The geographic dispersion of the participants from the four samples permitted identification of additional determinants of environmental valuation particularly associated with proximity to the project location, which increased the probability that the respondents had previously visited it. This effect of proximity and geographic heterogeneity (e.g. Bateman et al., 2006) increased the knowledge of the site and perception of direct environmental benefits received by potential offset buyers. At the end of Chapter 7, a corollary is presented integrating the information of the potential production of forest carbon services in La Primavera (Chapter 4) and the valuation of these services by users (Chapters 6 and 7). The information is used to estimate the required size of a local market in Guadalajara from the demand side.

1.3.5. Provision of Forest Carbon Services (Chapter 8)

Analysis of the potential provision of forest carbon services among landowners and communities (*ejidos*) owning forests in the study area is presented in Chapter 8. A choice experiment was applied to landowners and ejido members located in La Primavera and its unprotected wildlife corridors in order to explore the willingness to participate in projects enhancing and conserving forest carbon services. The PES program coordinated by CONAFOR is well known in the country; however, resources are not sufficient to engage all forest areas. The experiment asked landowners to consider enrolment in a PES-like program funded by a NGO aiming to conserve and enhance forest cover. In this case the experiment asked the participants to choose from different options that varied in the level of the cash payment offered, the length of the agreement and the possibility to receive other non-cash benefits for local development which could be included as part of the program (i.e. education, health, employment and/or productive projects). This type of program represents conservation programs with a more integrated approach to the valuation of natural capital (e.g. Bolsa Floresta in Brasil, Newton et al., 2012, Viana, 2008). Other questions were included to explore the likelihood of participation, the level of local land opportunity costs by agricultural production and urban development, the possibility to adopt agroforestry practices in cropland, and reforestation of grasslands. Results show the valuation of access to non-cash co-benefits, the potential for implementation for different management practices under different land property regimes and the effect of land opportunity costs. An appendix to Chapter 8 describes an implementation project which is being developed in the study area where a local user engaged in negotiations with an ejido to conserve a forest area and reforest a degraded area aiming to sequester carbon. A corollary is included to compare the figures of WTP obtained in Chapters 6 and 7 with the WTA by landowners.

1.3.6. A Proposal for Benefit Sharing under REDD+ (Chapter 9)

Chapter 9 presents a proposal for benefit sharing of carbon gains under REDD+ aiming to harmonise the rules of the institutional framework for the valuation of carbon benefits by exploring areas for public and private actions in market mechanisms. The topic of this chapter is not unique to the evaluation of the potential of local markets, the question of how to combine or share carbon credits between public and private sectors has not yet received much attention, and this is an issue that will inevitably affect local markets as well as international ones. Online with the initial description in Chapter 4, this chapter also includes a description of how the institutional framework under REDD+ is creating the rules for the quantification of carbon services; this is a critical initial step for the valuation of the services in both local and global markets. The negotiations of REDD+ have advanced in different areas related to how the baselines are set (UNFCCC, 2012a) and the definitions of the systems to monitor, verify and report carbon emissions and removals by sinks (UNFCCC, 2010a; UNFCCC, 2011b). However, two important issues have not yet been included in the decisions under the Conference of the Parties (COP) of the UNFCCC. These relate to creation of demand or other financing mechanisms for REDD+; and how benefits will be shared among the different stakeholders participating in the program (e.g. communities, landowners, international organisations, government). Although the latter is a subject which will be decided internally in countries participating in REDD+, due to matters of subsidiarity, the very nature of how carbon is to be accounted for under REDD+ imposes important challenges which can be generalised to countries participating in this program. The issues relate to the coupled quantification and valuation of reduced emissions from reduced deforestation and forest degradation *and* of increased carbon enhancements. The proposal presented in Chapter 9 indicates that by separating these two groups of carbon gains, emissions reductions and increased enhancements, and crediting them differently, can help to overcome many of the shortcomings identified. These two different streams of incentives for the valuation of carbon benefits are described: the valuation of carbon enhancements could be more readily linked to market-based mechanisms, which may enable individual landowners or communities to develop mitigation actions. On the other hand it will be more difficult to attribute the ownership of reduced emissions from deforestation and forest degradation at the parcel level; thus the valuation of these requires a certain level of data aggregation (and efforts) at regional or even national levels and should involve a higher participation of the public agencies concerned with forest management. In the final sections of this chapter the information obtained in Chapters 4, 6, 7 and 8 is used to evaluate the implications for public-private benefit sharing in La Primavera and to describe the role that the baseline set to estimate carbon services and carbon prices play in the level of incentives that could be generated under REDD+.

1.3.7. Conclusions (Chapter 10)

In Chapter 10 the main implications from the research chapters (Chapters 4 to 9) in the light of the current state of knowledge (Chapter 2) are integrated by addressing the main research questions posed in this Chapter to evaluate the potential for local market mechanisms for the valuation of forest carbon services. The final sections of this chapter briefly discuss the implications of the findings in the context of the use of market-based mechanisms for the valuation of environmental services by comparing local market mechanisms. Discussion is focused on the effects of the valuation of co-benefits of climate change mitigation activities and of transaction costs in the price and demand for mitigation action in local and global carbon markets. This chapter closes with the final remarks and reflections on the research.

2. Theoretical Framework and Gaps in Knowledge[2]

Governments are increasingly seeking ways of capturing the value of environmental services (ES) through policies that use market mechanisms to link producers of these services with their users. Important examples of this type of mechanism are PES programs and the carbon markets for climate change mitigation which are being implemented under the Kyoto Protocol, REDD+ and in voluntary markets (e.g. Pagiola et al., 2002; Peters-Stanley et al., 2011). Despite the fact that some of these markets have been in existence for almost ten years, there are still challenges to be resolved. In this chapter the background on the economic theory behind the use of market-based mechanisms for environmental policy is reviewed in the context of climate change mitigation; then the main issues for the valuation of forest carbon services in existing markets are described; this is followed by the depiction of a framework to assess the potential contribution of local markets for forest carbon services to local development as part of local climate policy. The final section of this chapter presents the main challenges and the gaps in knowledge associated to the valuation of forest carbon services in México based on a participatory workshop held in México in 2009. The gaps in knowledge serve to define the specific research questions of this research.

2.1. Market Mechanisms

Market mechanisms for ES have their theoretical roots in the 'Problem of Social Cost' (Coase, 1960) which combines the institutional arrangements associated with laws governing damage or wrongs (Law of Torts) with the efficiency of markets. The underlying theory is that legal 'command and control' measures and judicial prosecutions for regulating environmental damage can be costly, time consuming and not necessarily effective. In contrast, market-based instruments enable direct linkages to be made between parties affected by environmental damage, or the producer and consumer of ES. Once the link is established the parties can negotiate the supply of the environmental good at optimal levels, or the reduction of the negative externality, through 'Coasean Bargaining'[3] (e.g. Perman et al., 2003, page 137). Following Coase (1960), Zerbe (1980) condenses that preconditions for effective bargaining,

[2] Sections 2.1 and 2.4 of this Chapter are based on the material accepted for publication as book chapter, Balderas Torres, A., Skutsch, M. Lovett, J.C. In press. Retos para la Valoración de los Servicios Forestales de Mitigación del Cambio Climático (Book Chapter) in: Hernández, E. (Ed.) Recursos Forestales en el Occidente de México: Manejo, Producción y Aprovechamiento. Universidad de Guadalajara, Editorial Amaya, México.
Section 2.3 is based on material published in Balderas Torres, A., Lovett, J.C., Skutsch, M. 2009. Assessing the feasibility to link urban and rural areas through local markets for forest's carbon services and the potential for local development: a methodological proposal. Proceedings of the XIII World Forestry Congress. Forest in Development a Vital Balance, Argentina, 18-23 October 2009.

[3] This bargaining process is well represented by the common saying among lawyers in Mexico: 'a bad deal is worth more than a good lawsuit'.

these are that clear property rights over the good/service have been assigned, there is perfect information on the costs and benefits related to the goods/services being traded and there are no transactions costs needed to reach an agreement (Wohar, 1988). According to standard welfare economics theory, in order to maximise social welfare in unregulated markets it is necessary that actors possess complete and full information regarding the potential transaction to be made (Perman et al., 2003); in this case the information refers to the costs and benefits related to the ES.

Transaction costs refer to all the costs that need to be covered in order to make a trade and which might not be included in the price of the good or service itself. Following the text by Coase (1960), transaction costs relate to the search for a partner to trade with, information costs, negotiation and contractual costs, and the costs associated with the verification and enforcement of contracts. Other transaction costs in the context of the valuation of ES include all the initial costs necessary to set up the institutional framework under which transactions will take place, the cost of certification of projects, and the commissions charged by intermediaries or brokers. Obstacles to cooperation or transaction costs can thus be grouped into information or communication costs, free-rider costs and costs derived from strategic behaviour (Wohar, 1988).

Externalities are often used to diagnose market failures and thus justify public intervention, however, they arise fundamentally when transactions are made; externalities thus have their inherent origin in transaction costs which prevent the complete definition of property rights (Zerbe and McCurdy, 1999). According to the way in which exchanges are actually made, transaction costs can be classified into three groups: costs of search of partners to trade and information costs, bargaining and decision-making costs, and policing and enforcement costs (Dahlman, 1979). However, these classes can be fundamentally reduced to one: the cost associated to the lack of perfect information in different arenas (Dahlman, 1979). The identification of a problem as an externality, representing a sub-optimal social scenario (e.g. pollution or under-provision of ES), presupposes the knowledge of alternative scenarios where social actors would be better-off (Dahlman, 1979). Thus the generation of information associated with the costs and benefits of ES, the institutional framework to reduce the cost of their production, the study of social preferences, and the definition of the property rights are critical tasks for the valuation of ES.

2.1.1. Market Mechanisms for Environmental Values

As many ESs, such as the quality of the atmosphere, are public goods, there are some initial difficulties in creating an appropriate institutional framework whereby public goods can be traded in a market (Spash, 2010). As described by Corbera and Brown (2008), creating an institutional framework where exchanges for the valuation of ES might take place, brings with it different challenges: it needs to be supported by different social sectors (e.g. government, academia, communities); actors need to develop the appropriate capacities to participate in these schemes; and the framework needs to integrate the efforts of the relevant institutions consistently within the international rules and regulations (Corbera and Brown, 2008). Despite the difficulties of establishing these mechanisms, the scale of environmental problems and widespread market and policy failures in the provision of ES have made market-based mechanisms attractive.

Although the requirements for 'Coasean bargaining' are hardly met in practice (e.g. it will be hard to have no transaction costs), this principle has been the basis for establishing emissions trading initially in the US and now worldwide (Voss, 2007), and for the creation of PES programs (e.g. Pagiola and Platais, 2007; Muradian et al., 2010). Today the largest and most significant market is for carbon in the context of climate change mitigation. There are various types of market mechanisms for environmental valuation. In order to clarify how market mechanisms are defined in this research first the general characteristics of different market-based mechanisms are briefly described; these are: cap-and-trade with its extension to personal carbon trading, PES and voluntary carbon markets.

2.1.2. Cap-and-trade

Cap-and-trade is an economic instrument for environmental policy, which emerged as an alternative to command and control regulations since it enables the regulator to control pollution levels while reducing costs (e.g. Hanley et al., 1997). For this, a cap is set to indicate the limit acceptable of pollution in a system (e.g. country), thus an equivalent number of pollution units (permits) are distributed among the different emitters (e.g. firms). If the firms produce more emissions than the number of 'permits' they own during a given period, they are penalised. Thus firms have three options: to maintain levels of emission within their initial allotment of permits, to become more efficient and reduce emissions, or to buy permits from other firms willing to trade their own. Firms have different costs of controlling pollution, usually unknown to the regulator, thus in these schemes firms minimize the cost of pollution control by comparing their own abatement cost and the price of the permits in the market to the costs of non-compliance. After setting the cap and assigning the permits, the government needs to regulate trade and monitor the cap. Usually firms can trade the permits until these are retired from the market or they expire. In the context of climate change mitigation these permits are identified as 'Assigned Amount Units' (of emissions) at a country level; projects can produce extra units such as the certified emissions reductions (CER) under the CDM or emissions reduction units (ERU) in the joint implementation mechanism of the KP. These units are usually called carbon offsets as they substitute the emissions by the buying party.

Besides the ethical critiques made by environmental groups to the creation of 'rights to pollute' (e.g. Hanley et al., 1997), one potential flaw of emissions trading based on cap-and-trade is that the valuation of the environment is based in the creation of a perceived economic value, but not by the valuation of the resource itself (Tietenberg, 2003); this mutable sense of scarcity is traduced in the variable price for the permits subjected to supply and demand. Successful implementation of these mechanisms thus rely heavily on the level of the baseline set (cap, emissions reduction target); the design of legal, monitoring and enforcement systems ensuring certainty in the long term; an efficient administrative system and a transparent framework for transfers (Tietenberg, 2003). One weakness of global emissions trading is the poor institutional capacity at the international level to enforce effectively penalties for non-compliance (Schelling, 1997, 1998, 2002; Aldy et al., 2003). Despite the critiques, it looks like market-based mechanisms arrived to stay in climate policy since they give opportunities to powerful actors in the financing sector to start new cycles of investment and economic growth in coalition with some environmentalist groups (Patterson, 2012).

2.1.2.1. Personal Carbon Trading

Although many countries are preparing emissions trading systems (e.g. Grubb and Sato, 2009), these schemes usually are confined to upstream sectors of the economy (e.g. private sector, especially energy intensive facilities) (Aldy et al., 2003). One of the reasons for this is because of the large administrative costs of involving the whole population in such trading (Lockwood, 2010). However, involving civil society into personal carbon trading has the potential to engage the general public into active climate change mitigation thus helping to promote the behavioural changes needed (Fawcett and Parag, 2010); it can also help to define and distribute the environmental property rights (Fawcett and Parag, 2010). Similarly to standard emissions trading, personal carbon trading would require the allocation of emission quotas to citizens which would have to be surrender for every activity made, as in existing schemes the quotas could be traded among citizens (Parag and Eyre, 2010). The implications of personal carbon trading have been analysed for different developed countries (i.e. the US and some countries in Europe) (Fawcett, 2010). At the micro level the potential for carbon trading could have different scopes (Fawcett and Parag, 2010), it has been analysed considering the emissions of the whole economy (FEASTA, 2008), or targeting specific sectors as energy consumption at household level (Niemeier et al., 2008; Eyre, 2010) or emissions from private road transport (Raux and Marlot, 2005). The analysis of carbon based market mechanisms at the micro level has not been made for forest carbon services in developing or emerging economies as México.

2.1.3. Payments for Environmental Services (PES)

The main advantages attributed to market mechanisms for the valuation of ES is that they promote the efficient use of resources through the balance between ‘supply’ and ‘demand’ (Landell-Mills and Porras, 2002), and facilitate the adoption of targets for natural resource management aligned to a greater social interest (Muradian et al., 2010). As mentioned in Chapter 1, usually PES programs refer to voluntary transactions between at least one provider and one user for the provision of defined ES subjected to conditionality (Wunder, 2005). It is the negotiation between the provider and the user what resembles the Coasean bargaining. The basic elements in the design of these programs include: definition of the service which is to be valued, the objective of the program, scale of implementation, estimation of potential supply and demand, and establishment of an appropriate regulatory/institutional framework (Landell-Mills and Porras, 2002). However, PES and emissions trading from cap-and-trade have substantial differences.

2.1.3.1. Some Differences between Emissions Trading and PES

An essential difference between cap-and-trade and PES is the way in which the prices to value the environment are set. In PES, valuation is initially motivated by the scarcity of a natural resource itself, caused by their continued degradation (Kinzig et al., 2011; Kroeger and Casey, 2007). Thus PES programs usually target geographically specific natural resources to be directly valued. However, considering the problems to coordinate a large number of buyers (e.g. all the users in a watershed), in PES the government usually acts as a unique buyer on behalf of the users of the ES, as is the case of the national PES program in México (Muñoz Piña et al., 2008); thus in PES programs there is no room to 'trade' the ES as in cap-and-trade. In this context the payment or price of the ES is traduced in a fixed flat rate payment. The outcome of the intervention is usually not measured exhaustively in quantitative terms as opposed to the straightforward quantification of offsets; sometimes it is assumed that the qualitative conservation of certain environmental attributes (e.g. forest cover) is enough to ensure the provision of the ES (e.g. water services, biodiversity conservation). Financing is not necessarily linked to users; in fact sometimes, environmental taxes or tariffs paid for the use of environmental resources which may not be enough to motivate change in behaviour among users (e.g. firms or citizens) are considered only as revenue rising mechanisms for the public budget (Hanley et al., 1997), not necessarily earmarked to environmental programs. In practical terms the environmental values are insensitive to demand and the sense of scarcity of the ES among the users. Payments are usually offered to potential providers in open tenders, constrained by the public budget; landowners or communities decide voluntarily whether they apply or not but usually cannot negotiate the level of the payment.

2.1.4. Voluntary Local Markets for Forest Carbon Services

As commented in Chapter 1, the basic difference between compliance and voluntary market resides in the motivation of buyers to participate in the scheme. Voluntary markets differ from compliance markets based on cap-and-trade systems in the sense that environmental valuation is not based on an artificial value set by the institutional framework (i.e. the cap and penalties), but on positive reasons that can be more directly linked to the environmental resources (e.g. environmental responsibility, conservation of a specific area or species, increased revenues from green marketing). In this sense they could be considered remotely similar to PES since projects can be developed in specific geographical areas as means to contribute to generate specific benefits (e.g. biodiversity conservation, forest conservation). However, they are substantially different to PES in the sense that providers and users can flexibly meet and negotiate different prices and level of provision (amount of offsets); this process usually takes place through intermediaries or brokers. Transactions in the voluntary markets are as in emissions trading, based on the amount of emissions reduced or carbon removed from the atmosphere by forests in terms of tonnes of carbon dioxide (tCO_{2eq})[4]; thus voluntary markets offer incentives based on quantitative performance similar to cap-and-trade which are sensitive to demand and supply in terms of quantities and price setting. Although the scale of voluntary markets is still slim (Peters-Stanley et al., 2011), it can offer an opportunity to engage individual action to mitigate climate change as intended by personal carbon trading.

In this research the study of the potential for local market mechanisms for the valuation of forest carbon services is based on the model offered by the voluntary carbon markets. A local market

[4] In forestry based projects, equivalents of carbon dioxide, CO_{2eq}, refer to the conversion of a tonne of carbon stored in biomass measured as carbon (C), to its equivalent amount as atmospheric carbon dioxide, for this the ratio 44/12 tCO_{2eq}/tC is used. In a more general way CO_{2eq} also indicates the conversion of emissions of other GHG as methane, into CO_2 equivalents, which is the standard unit of measurements; conversions are made considering the global warming potential of each GHG different to CO_2. (e.g. 1 tonne of methane is equivalent to 25 tonnes of CO_2 (UNFCCC, 2012a)).

would allow the voluntary negotiation between users and providers to set the provision and financing level based on the quantification of the forest carbon services; this is similar to the initial definition of PES provided by Wunder (2005), however, here the emphasis is made in the potential for independent negotiations of the provision and financing levels for each agreement resembling the voluntary carbon markets rather than public PES programs.

2.1.5. Limits of Market Mechanisms for Valuation of Environmental Services

It is necessary to emphasize that it is not possible to expect that market mechanisms alone will be able to resolve the problems associated with loss of ESs and deforestation and forest degradation. These policies may be an option in cases where there are no other major market failures present and a large share of the ESs are indeed external to regular markets (Engel et al., 2008). When other kinds of market failures prevent landowners and communities from adopting economically profitable forest management practices that would by themselves enhance or conserve the ES, the other market failures and policy distortions should be addressed first (Engel et al, 2008; Heath and Binswanger, 1996). Examples of such market failures relate to the lack of clear land ownership rights, to failures in the implementation of legal frameworks, to lack of information on the costs and benefits of the ES and lack of access to credit/financial options (Engel et al., 2008). Information on costs and benefits of the ES and the means to realise them, is required not only to adequately design the market-based mechanisms, but also to evaluate if these schemes are the best option available to fulfil a specific environmental goal.

2.2. Challenges for the Valuation of Forest Carbon Services in Existing Carbon Market Mechanisms

2.2.1. International Carbon Markets

The valuation of carbon in compliance international markets is strongly determined by the emission reduction targets and the procedural rules set in the negotiations under the UNFCCC. There are various factors that hamper the demand for forest carbon credits in existing markets, thus limiting their contribution to climate change mitigation. One is the low cap set in the emissions reductions targets adopted under KP (5% of emissions levels in 1990 as mentioned in Chapter 1). Demand was limited not only because of the low target set, but also because the US, the largest GHG emitter by the time, did not ratify the Protocol. Another factor was the economic crisis since the late 2000’s that has slowed down economic activity in developed countries and associated GHG emissions, thus reducing the demand for carbon credits in international markets. An additional issue in international compliance carbon markets is that it is virtually impossible under current circumstances to enforce compliance with the agreed emission reduction targets or to impose fines on those failing to meet their obligations in this regard (e.g. Aldy et al., 2003). Moreover, the consideration of co-benefits of climate policy implementation in financing countries may reduce the demand in international markets (e.g. Pearce, 2000). It has been the consideration of co-benefits, along with the generation of economic savings of some mitigation activities (e.g. energy saving), what has motivated the design and implementation of climate policy at the local level (e.g. in cities in the US) (Kousky and Schneider, 2003).

Furthermore, it has been difficult to negotiate more ambitious legally binding emissions reductions targets for a second period of the Kyoto Protocol starting after 2012 thus failing to give certainty to the market. In fact in 2011, Canada, Russia and Japan expressed their intention of not renewing their commitments for the second period of the Kyoto Protocol; Australia and New Zealand have not confirmed their participation yet (UNFCCC, 2011c). This weak demand for credits associated to the difficulties in negotiating more ambitious emissions reduction targets for the second period of KP (2012-2017) is reflected in the prices of carbon credits in international markets which have fallen to a record low reaching \$4.92/tCO_{2eq} by the end of 2011 (for CDM's CERs) (Krukowska and Carr, 2011). Between 2007 and 2008 the value of the European Union Allowances (EUA), which are the carbon units traded in the European Union Emission Trading Scheme (EUETS), was stable in the band of €20 to 25/tCO_{2eq}, this was a good signal for the investment for CDM projects (Capoor and Ambrosi, 2008). It was then expected that future prices for CDM after 2012 would be as high as €48/tCO_{2eq} (Capoor and Ambrosi, 2008).

The implementation of activities under the UNFCCC creating the institutional framework for the carbon markets has not been particularly rapid. Aside from the problems to guarantee the compliance with the agreed emissions reduction targets there have been also difficulties with activities such as the preparation of inventories of GHG emissions and removals and national communications to the UNFCCC. These are important aspects since they provide the input for the design of climate policy and goal setting; the levels of emissions also serve to estimate the potential for demand and supply of credits at the international level. As an example, the convention text signed in 1992 stipulates that countries should prepare periodic national communications to the UNFCCCs including the inventories; still after 20 years by April 2012 there were twelve non-Annex I countries (developing countries) which have not submitted their first communication (UNFCCC, 2012b)[5]. This shows the difficulties in the agreement on the methodologies, frequency for reporting and resources for their preparation under the Conference of the Parties (COP) of the UNFCCC.

There are other reasons why the international carbon market may not be as economically efficient as portrayed by economic theory. The intangibility of ES and the international nature of the market makes it difficult to verify the outcomes of the projects selling the offsets and creates a principal-agent problem in which the buyer cannot directly monitor the actions of the supplier (Murray and Dey, 2009; Spash 2010). Moreover, complex, costly and slow procedures for the registration of projects restricts access to the market for potential developers. All these factors increase total mitigation costs, especially transaction costs related to monitoring, certification and verification, thus reducing the efficiency.

[5] In April 2012, 12 non-Annex I countries had still not yet submitted their first communications to the UNFCCC, 51% of countries had submitted only one communication (79 countries), 62 countries had submitted two, Uruguay three and Mexico four (UNFCCC, 2012b)

2.2.2. Carbon Markets and Forest Carbon Services

The poor demand associated with the low mitigation targets affects carbon markets in general. However, one structural factor in the design of the international markets limiting the valuation of forest carbon services is the fact that forest carbon credits are considered 'temporary' as opposed to the 'permanent' credits offered by other mitigation projects (*i.e*. renewable energy). The rationale for this lies in the fact that carbon removals and storage in forests are potentially reversible (*e.g.* harvests, pests, fires). However, credits from other projects reducing the extraction and use of fossil fuels (*i.e.* energy efficiency and renewable energy projects) cannot be regarded as permanent, since there is no guarantee that the oil not extracted and burnt one year would not be emitted the year after while it is still economically viable (Skutsch and Trines, 2010); in this sense both clean energy and forestry-based projects reduce the rate of emissions reductions in similar ways (Skutsch and de Jong 2010). Nevertheless, carbon credits for carbon sequestration under the CDM were labelled 'temporary' (UNFCCC, 2004) and the contribution of forestry-based actions to emissions reductions targets in KP was capped to 1% (UNFCCC, 2002). Concurring with this the EUETS, by far the largest compliance carbon market in the world (Peters-Stanley et al., 2011), decided to exclude forestry-based credits entirely (CEC, 2003), thus reducing the market for carbon sequestration credits. Forestry-based climate mitigation activities eligible for participation in CDM were limited to afforestation and reforestation projects thus activities aiming to reduce emissions from deforestation and forest degradation could not receive incentives from these markets.

Although forestry-based projects perform better in voluntary carbon markets where they accounted for 40% of the volume in 2010, the size of this market is minimal, accounting only for 0.02% of carbon traded globally (Peters-Stanley et al., 2011). In response to this situation, a new policy, REDD+, is currently being negotiated within the UNFCCC. Under REDD+ developing countries may receive support for a range of activities that reduce emissions and increase carbon removals by forests (UNFCCC, 2010a). Each country participating in REDD+ may implement its own selection of policies to control deforestation and degradation; measures could include improved judicial and legal frameworks and controls or incentive programs such as internal carbon markets or PES which could potentially address the issues present in existing markets. In the case of México, a variety of options are being discussed in the context of the national strategy for REDD+ (CONAFOR, 2010).

2.2.3. Climate Regime Post-2012

Partly due to the difficulties of negotiating international legally binding agreements and partly because of the need to engage more countries in the post-2012 climate regime (*e.g.* the US and recently industrialized countries with high level of emissions such as China, India, Brasil, South Africa or México), the importance of nationally appropriate mitigation commitments and actions adopted domestically by different countries is growing in the climate regime. After the Copenhagen meeting in 2009, developed and developing countries, including México as mentioned in Chapter 1, started reporting to the UNFCCC their objectives and actions to mitigate climate change. In Cancun during COP 16 the UNFCCC officially took note of the voluntary actions and targets expressed by both developed and developing countries (UNFCCC, 2011b). These voluntary targets might increase the demand for forest carbon services; in some countries the strategies will include the development of national or sub-national market-based mechanisms.

With this in mind it is important for countries like México to re-evaluate the implications of participating in a global carbon market. If carbon credits generated by market mechanisms such as CDM or those generated under REDD+ are to be sold to Annex I or other countries as offsets, they would be counted as reductions for the purposes of the purchasing countries and would not be 'available' for México to achieve its own target. This could mean that credits from the most cost-effective mitigation options (i.e. those generating more credits at lower cost) would be sold abroad, and that national actors (i.e. firms and citizens), who must reduce their own emissions by 2020 or 2050 would be faced with higher cost emission reduction options. For this reason it is doubly important that México develops strategies for local carbon markets that, to the greatest extent possible, retain at least some of the cost-effective options for use for its own national emissions reduction target. Moreover, if local markets are to contribute to local climate and environmental policies as expressed in the national REDD+ program (CONAFOR, 2010) it is necessary to assess the feasibility of their development and their potential contribution to achieve the emissions reductions targets.

In this research the potential for local markets for forest carbon services is analysed to discuss the potential contribution these could play to climate policy in México. In this context the feasibility depends initially on the willingness of buyers to finance the provision of the services and the willingness to accept of producers to supply them. Then its potential contribution to climate policy can be assessed in terms of how much these mechanisms can contribute to reduce local emissions.

2.3. Local Markets to Link Urban Users and Rural Suppliers of Carbon Services

This section describes a theoretical proposal to link users and suppliers of forest carbon services at the local level by considering separately urban and rural areas. Rural areas usually have larger proportions of its natural capital conserved compared to urban areas, which tend to be the location of productive, social, human and financial capital. This generates an asymmetric development model especially in developing countries. Depending on the activities developed within a territory an analysis of the local carbon balance (emissions-removals) can be performed to classify different areas as providers or users of carbon services. The objective of this section is to describe the framework for utilizing the carbon balance at the local level to identify the potential for local carbon markets and its implications for climate policy. The identification of potential producers or users of carbon services offers an initial guideline to identify the potential for local markets and shape the requirements for sustainable development.

2.3.1. Sustainable Development and the Livelihoods Approach

In order to contextualize the role that market mechanisms based on environmental values can play in local development, development and sustainable development need to be defined first.

According to the livelihoods approach along with financial, productive, human and social capital, natural capital plays a critical role for the development of livelihoods (Carney, 1998); the same approach based on these five capitals is also used to measure indicators for sustainable development at the macro scale (UNECE, 2008). The future potential for development is defined by the current levels of the stocks and flows of the five types of capital (UNECE, 2008). Sustainable development was defined initially as the type of development that "seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future" (WCED, 1987); however, this definition does not provide guidelines on how it should be measured and implemented. The United Nations in the Handbook of National Accounting - Integrated Environmental and Economic Accounting, SEEA- provides a more detailed definition of sustainable development as the 'development that ensures *non-declining per capita* national wealth by replacing or conserving the sources of natural wealth; that is, stocks of produced, human, social and natural capital' (UN, 2003). Then it is not only the level, but the *combination* of different stocks and flows of capital –built in the past, inherited from past generations and present in a specific territory- what defines present and future potential for development.

2.3.2. Towards a Sustainable Rate of Carbon Emissions and Removals

In order to prevent the consumption and depletion of natural capital Daly (1990) suggested two sustainability rules. First, the use of renewable resources should not be faster than their regeneration rates; and second the emissions, discharges and generation of wastes should not exceed the capacity of the ecosystems to assimilate them (Daly, 1990). Any deviation from these criteria may consume the natural capital and will make any activity non sustainable. In order to provide an implementation guideline for sustainability here these two principles of sustainability are complemented by the adoption of a Rawlsian perspective (Rawls, 1971). If the use of resources –and generation of emissions/wastes- in the *present and local scales* is sustainable, then it will be more likely that the use of resources and interactions between man and nature will be sustainable at the regional and global scale in the future. Following the second principle of sustainability of Daly, climate change and the accumulation of GHGs in the atmosphere is derived from the historical imbalance between the emissions which out-pace removals by sinks. Following this principle the maximum amount of emissions allowed to maintain GHGs concentrations within a sustainable balance should consider the quantity of carbon that can be assimilated by the biosphere in carbon sinks.

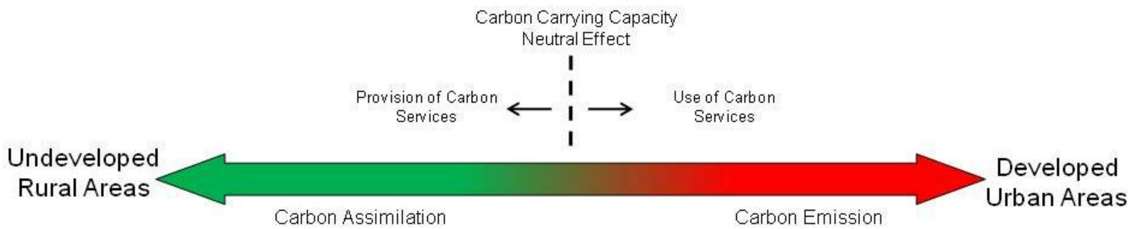
2.3.3. Valuing the Provision of Carbon Services

For the framework here proposed the forest-related activities generating carbon benefits (i.e. sequestration, enhancement and reduced emissions) are grouped as activities providing carbon services; these include the activities under the CDM, the voluntary carbon market, PES programs for carbon services and REDD+. All of these would be eligible to receive payments for the forest carbon services produced. Landowners in rural areas can change the provision of forest environmental services –positively or negatively- depending on their decisions in land use and management; however, ultimately the services are provided by the organisms –plants, animals- and the geophysical conditions present in the land or territory. The environmental services are ‘provided’ by the landowners, as far as the property rights over the land hosting the ecosystems are present and land use management generates measurable benefits. With exception of some activities which would be implemented by the government under REDD+ in general, activities providing carbon services are based on the implementation of projects directly by landowners and communities. Since poverty is correlated with low consumption patterns, hence – aside from deforestation and forest degradation- it is expected that landowners in marginal rural areas would be providers of environmental services since local emissions are expected to be comparatively lower. Nevertheless, population density will play an important role to assess the carrying capacity of the territory. In order to obtain the carbon balance (assimilations-emissions) at the local level the analysis needs to consider emissions from all the sectors of the economy; here the analysis is proposed at the local level in the city of Guadalajara and La Primavera.

2.3.4. Local Carbon Balance

After the carbon emissions and removals are estimated at the local level, then it will be possible to classify an area as being a potential provider or user of carbon services, or a carbon neutral region (Figure 2.1).

Figure 2.1 Local Carbon Balance.



Land, and landowners, in areas providing carbon services could be entitled to receive a payment for the services provided. These areas will have the potential to create ‘closed’ local markets since emissions could be offset locally. On the other hand, areas classified as users of carbon services, may be accountable to pay for the carbon emissions produced or atmospheric services they use and would need to participate in a regional or international market. The scale of net emissions in areas with net emissions will also indicate the need for emissions reductions to reach a sustainable rate; an alternative approach would be to estimate increases in carbon removal yields needed to offset the emissions by local forests.

2.3.5. Valuation of Forest Carbon Services and Local Development

From the livelihood approach to development, rural undeveloped areas will be the holders of important stocks of natural capital while urban developed areas may be the recipients of the stocks (infrastructure, assets) of the financial, productive, human and social capital; ‘developed’ areas may have transformed and reduced or even deployed their original natural capital assets. Just as the population in urban areas might be thought of as user of environmental services provided in rural areas, the population of rural areas could be considered as a user of some goods and services originated in urban or more developed areas. Wherever there is a human group inherently there will be a certain degree of financial, productive, human and social development understood in the broader sense; here the emphasis is in the location of the assets associated with each form of capital to link rural areas to natural capital and urban areas to the other forms of capital. In the case of social capital it refers to the physical location and assets related to formal institutions.

In order to assess the potential contribution that the valuation of forest carbon services to local sustainable development, in areas with the potential to provide carbon services, the potential revenues from the valuation of these services can be estimated. These benefits could be expressed not only in terms of income but also in terms of potential investment to increase locally other forms of capital and capacities, and ultimately for local development. Moreover, the bargaining between providers and users in market-based mechanisms for the valuation of ES can include the provision of in-kind or non-cash sources of compensation improving the five types of capital (e.g. Landell-Mills and Porras, 2002). In the study of the implications of local markets for forests carbon services in México, the use of the local carbon balance permits identifying the potential that the forest sector can play in climate policy; the inclusion of a broader view to the development based on the livelihood approach can help to shape the potential contribution of the valuation of these services to local development.

2.4. Challenges for the Valuation of Forest Carbon Services in México

This chapter finalises by presenting a review of the challenges for the valuation of forest carbon services in México. A participatory 2-day workshop was organised in February 2009 in Guadalajara, México, to identify the causes of deforestation and forest degradation and the information necessary for development of local market mechanisms for ES. This workshop was made possible through the assistance and participation of representatives from academia, civil associations, ejidos (agrarian communities) and the public sector at local, state and federal levels. The objective of this section is to identify in the Mexican context, the potential role that market-based mechanisms could play in domestic climate policy and the specific gaps in knowledge for their implementation. The gaps in knowledge relate to the quantification, provision, valuation and the institutional framework for forest carbon services and are used to identify the gaps in knowledge and refine the research questions.

2.4.1. Workshop set up

The purpose of the workshop was to gather a wide range of actors involved in forest resource management to develop a consensual analysis on the causes and consequences of deforestation and forest degradation and on the gaps in knowledge associated with development of local markets for the valuation of ES. The workshop used the ZOPP methodology (objective oriented strategic planning, NORAD, 1993). Working sessions included plenary discussions, general presentations and teamwork. More than 30 actors from different sectors were involved, mostly from the state of Jalisco. The organisations represented were[6]:

- Academia: TSD-CSTM, CIGA-UNAM, ITESO, CIESAS, COLMEX, ECOSUR.
- Ejidos: La Primavera, Lazaro Cardenas, Villa Corona.
- NGOs: Corazon de la Tierra, ALICEA, Reforestamos México, AMBIO, Consorcio Sierra Gorda of Queretaro, CCMSS.
- Government: SEDER, SEMADES, PROEPA, INE, CONAFOR, Department of Ecology of Zapopan, Executive Director of La Primavera, Technical Micro-watersheds of the municipalities of Zapopan and Talpa de Allende.

During the first day, the first questions presented to the participants to start the discussion were:

1. Who are the actors involved in the economic valuation of forest ES in México?
2. What are the causes and consequences of deforestation and forest degradation in México?

Participants identified several factors associated with the questions. The causes of deforestation and forest degradation were grouped into four general themes describing the main problems identified; subsequently an analysis of possible solutions was conducted. The second day of the workshop focused on the analysis of the challenges for the implementation of market mechanisms, with special attention to the identification of gaps in knowledge. Participants formed four working groups, each of which focused on the identification of necessities for the development of market mechanisms in a specific area (i.e. quantification of ES, supply, demand and institutional framework). The following questions were used as guides:

1. What technical information do we need about ES (carbon, biodiversity, water...) to develop a successful payment system?
2. What do we need to know about the needs of communities and farmers, to enable them to participate successfully in a market for ES?
3. What do we need to know to design a system that engages local consumers/users in a market for ES?
4. What do we need to know in order to develop an institutional framework for a national payment system/market that links producers and consumers/users?

At the end of the workshop each team presented their findings in plenary sessions, which were followed by question and answer sessions. The information gathered at the workshop was organised to identify the main market and public failures associated with the causes of deforestation and forest degradation, and those preventing the adoption of their associated solutions. In this context the role of market mechanisms for the valuation of forest carbon services is bounded. Below are the results of the two stages of the workshop.

2.4.2. Identification of Actors

Box 2.1 lists the different groups of participants and stakeholders identified related to the management and valuation of forest ES. Actors are grouped according to their roles in market-

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[6] The definition of the abbreviations/acronyms of the institutions that participated in the workshop are included in the list of abbreviations after the table of contents.

based mechanisms, and include both the providers and users. The government sector is represented by a number of actors that influence forest management from the municipal level, state level and federal governments. The regulatory framework for a market of ES will have to consider how it is going to interact with the relevant actors from the public sphere. The academic sector is perceived as a source of information for technical support and to provide substance to any program of ES. Some actors, particularly NGOs and project developers, were identified as initiators of projects in rural areas or intermediaries linking producers and users.

Box 2.1 Who are the actors involved in the economic valuation of ES provided by forests?

Public Management / Institutional Framework.

Federal Government: SHCP, SEP, CONANP, SECTUR, SE, SAGARPA, CONAFOR, CONAGUA, PROFEPA, SSA, CFE, SEMARNAT, Judicial Power, Legislative Power.

State Government: Water Commission, SEDER, PROEPA, Local Ministry of Environment and National Protected Areas, water supply bodies, local congress.

Municipal Government: Water supply bodies, local tourism offices, municipal natural protected areas, municipal department of ecology, urban development office.

Users of ES: Citizens, farmers, tourists, residents, visitors, private sector (construction firms, urban developers urban, industries and service sector benefiting from the 'added value' provided by the forests; hedonic value for housing developments, restaurants and touristic services).

Providers of ES: Ejidos and communities, landholders (private, communal, state).

Information Providers: Academia, researchers, students, consultants, environmental commissions and public institutes (e.g. INE).

Others: Brokers or intermediaries, NGOs, project developers, banks, political parties, developed countries, international/multilateral organizations.

Box 2.2 Causes and consequences of deforestation and forest degradation in México.

Causes and Consequences	Barriers and Underlying Failures
1. Lack of Governmental Coordination. Government programs are uncoordinated; lax legislation, inadequate policies, perverse subsidies, failure to apply sanctions, failures in forest management, inefficient management and organisation of Natural Protected Areas, corruption, lack of resources and trained personnel, lack of well-resourced inspection and supervision services, proliferation of illicit activities, research results do not reach the decision makers.	○ Coordination transaction costs. ○ Perverse incentives. ○ Public regulation enforcement failure (vigilance, inspection and judicial processes). ○ Lack of capacities. ○ Incomplete information.
2. Agricultural and Livestock Activities. Agricultural use of fire, high international price for agricultural and livestock products, expansion of cropland and grazing areas, poor dissemination and adoption of sustainable technologies (e.g. efficient cook stoves), rural poverty and lack of financial services, high income from sale of land, lack of alternatives for rural producers.	○ Failures in the transfer and adoption of new practices and technologies. ○ Incomplete information. ○ Environmental externalities not included in prices (land, agricultural goods). ○ Poor financing options. ○ Public regulation enforcement failure (land use regulation, fire management).
3. Land Use Change. Profitability of biofuels, uncontrolled tourism, deforestation, land use change for economic activities, urban growth, on-going urban expansion, construction of infrastructure (e.g. roads).	○ Public regulation enforcement failure (land use regulation, planning of infrastructure). ○ Failures in the transfer and adoption of new practices and technologies. ○ Environmental externalities not included in prices (land, housing, biofuels). ○ Incomplete information
4. Unsustainable/Illegal Logging. Consumer demand for forest products (timber), inefficient use of timber resources, bureaucratic process to register officially timber exploitation projects, clandestine logging.	○ Environmental externalities not included in prices (timber and non-timber products). ○ Public regulation enforcement failure (Forest Policy, Judicial vigilance). ○ Transaction costs of legal timber exploitation. ○ Incomplete information.
Other. Poor reforestation practices, natural disturbances such as hurricanes, pests, lack of sustainable development models, lack of governance and collective organization, population growth, lack of environmental education	○ Failures in the transfer and adoption of new practices and technologies. ○ Low social capital. ○ Incomplete information.
Consequences. Negative environmental impacts, desertification, disarticulation of social actors, loss of organic matter in soils, decrease in vegetation cover, climate change, biodiversity loss and species extinction	○ Negative externalities, reduction of positive externalities.

2.4.3. Causes of Deforestation and Forest Degradation

The causes of deforestation as expressed by participants can be grouped into four major areas (Box 2.2). The main causes were: lack of coordination in the government sector, mismanagement of farming and livestock-including forest fires-, deforestation for land use change, and illegal logging and unsustainable harvesting of timber. The results presented in Box 2.2 describe the problems in general. Some causes may appear in connection with more than one problem, and even appear as a result (e.g. Rural Poverty), owing to the vicious cycles involved.

Box 2.2 (and also from Box 2.2 to Box 2.6 in the following sections) present the barriers and market/public failures associated with the causes of deforestation and forest degradation and those preventing the adoption of possible solutions; this will allow evaluation of the role that market-based mechanisms may play in México, but highlights also the presence of other market failures which may intervene (Engel et al., 2008). Box 2.2 shows various public and market conditions which may affect the supply and demand of ES; these failures need to be considered when identifying the situations in which market mechanisms would be likely to succeed.

2.4.4. Solutions

As part of the workshop, the solutions to the problems identified in the previous section were identified. Sections 2.4.4.1 to 2.4.4.4 present the solutions identified for each of the four problems.

2.4.4.1. Coordination of Public Sector

The main suggestions for addressing problem 1 and contribute to the coordination between different ministries and across governmental levels, were to create agencies and mechanisms to standardize the environmental agenda and to reorient efforts so that they work towards common goals which include the conservation, valuation and provision of ES. These views coincide with the findings by Corbera and Brown (2008) stressing the challenge represented by the inclusion of all the relevant public organisations in the design and creation of the institutional framework for markets to value ES. Box 2.1 presents a detailed list of the actors that might be related to the design of such an institutional framework; or whose operations are related to one of the main roles identified in the market (*i.e.* quantification, provision, demand and regulation).

Considering the number and diversity of stakeholders it can be expected that the transaction costs for the coordination and agreement of the institutional framework will be high. The definition of property rights over the benefits of ES and the appropriate design of the institutional framework might promote linkages between providers and users, for instance through the alignment of incentives for participation and reduction of transaction costs (*e.g.* operative costs, negotiation, costs of verification and enforcement of agreements). It is envisaged that public and civil society organizations should play a participatory role in this (Box 2.3).

2.4.4.2. Agricultural and Livestock Activities

It was noted that problem 2 has been resolved on a small scale in some places, *e.g.* through organic farming, agroforestry techniques or alternative livestock farming. However, these solutions have not been implemented on a larger scale yet, which may be a sign of other failures (*e.g.* incomplete information, poor access to financial services and technology) (Box 2.4).There are incentives conflicting with the provision of ES (*e.g.* agricultural services not incentivizing productivity) that need to be considered in the solution of problems 1 and 2.

2.4.4.3. Land Use Change

As in problem 2, the proposed solutions to problem 3 are related to the implementation of technical measures e.g. technology transfer, capacity building for endogenous development and self-regulation and land use regulations. Likewise these solutions already exist but have not been implemented widely or effectively, this probably reflects other types of market or public failure; failures may also reflect problems associated with the lack of specific capacities or low social capital for collective action in certain regions. It is also important to mention in this context that policies such as PES and market mechanisms are identified as means to create alternative economic options in rural areas (Box 2.5).

2.4.4.4. Illegal Logging

In the analysis of solutions to problem 4, participants mentioned that this issue arises because the inspection and monitoring processes surrounding timber harvesting are not effective and because the legal and sustainable use of timber often imposes financial burdens on the owner; moreover, those interested in developing them usually face costly bureaucratic processes. Another cause is the fact that much timber harvesting is illicit, sometimes even being carried out by criminal groups. Thus proposed solutions are oriented to the simplification of procedures for regulated use of forestry resources and strengthening and enforcement of the regulatory framework (Box 2.6). The underlying failures that have prevented the adoption of these solutions relate to the high transaction costs of the bureaucracy needed to undertake regulated forest management as well as public failure in the enforcement of the existing regulatory framework.

Box 2.3 Solutions to problem 1: lack of coordination in public administration.

Solutions	Barriers and Underlying Failures
o Create an interdepartmental and intergovernmental agency integrating the federal, state and municipal levels to define criteria and actions related to forest management. o Define basic criteria for program support and resources and eliminate perverse incentives. o Creation of an independent body to evaluate and recommend public policies at different levels. o Promote a network directory to link the various actors involved in forest management. o Establish a national market for carbon sequestration	o Coordination transaction costs. o Communication transaction Costs. o Transaction costs for the establishment and maintenance of the institutional framework. o Incomplete information.

Box 2.4 Solutions to problem 2: Poor management of agricultural and livestock activities, including fire.

Solutions	Barriers and Underlying Failures
o Disseminate and apply regulations applicable to fire management (*e.g.* NOM-015-SEMARNAT/SAGARPA-2007, SEMARNAT/SAGARPA, 2009). o Train communities' fire brigades (vigilance, monitoring, maintenance to fire breakers). o Promote an integrated agricultural management / agroforestry o Promote organic agriculture, composting, recycling, vermin-compost, etc. o Define carrying capacity for grazing. o Improve the genetic selection for cattle, promote the use of alternative/wildlife species for grazing and units of environmental management (UMA).	o Incomplete information. o Lack of capacities. o Failures in the transfer and adoption of new practices and technologies. o Poor financing options.

Box 2.5 Solutions to problem 3: land use change.

Solutions	Barriers and Underlying Failures
Change in land use caused by urban development: o Compliance with urban development plans. o Monitoring of compliance by civil society and media. o More efficient use of natural resources in cities and industry. o PES as economic alternatives in rural areas. o Raise awareness of forest culture (awareness of the relationship between forests and city). o Enforce compliance with environmental impact assessment.	o Public regulation enforcement failure (land use and environmental impact assessment regulations). o Value of environmental services not included in prices. o Poor collective action. o Prices are not economic incentives to promote the efficient use of natural resources. o Incomplete information.
Land use change caused by farming activities: o Adoption of best agroforestry practices. o Capacity building for local governance, endogenous development and technical innovation. o Technology transfer: fire management, organic practices, agroforestry practices. o Create markets/incentives to provide ES. o Ensure compliance with regulations/ standards o Identification of areas providing ES in land use planning policies (implementation and compliance).	o Failures in the transfer and adoption of new practices and technologies. o Poor financing options. o Value of environmental services not included in prices. o Public regulation enforcement failure (land use regulations).

Box 2.6 Solutions to problem 4: unsustainable and illegal logging.

Solutions	Barriers and Underlying Failures
o Reform of the system of inspection and supervision of timber harvesting. o Modify legal attributions of prosecution bodies (e.g. PROFEPA). o Consider environmental inspection and monitoring processes as a matter of national security. o Strengthen sanctions to illegal sawmills and punish non-compliance. o Publish a manual for inspection and enforcement procedures. o Increase transparency in the monitoring of complaints, using online systems. o Increase efficiency of management processes and monitoring inspection, with trained and well paid staff. o Increase efficiency of administrative processes and permits for sustainable management and use of forests. o Generate technical capacities and infrastructure for environmental programs. o Ensure permanence and continuity of environmental programs. o Continue the dissemination of environmental activities, develop a communication strategy. o Provide incentives for municipalities with a good environmental performance. o Pool resources from fines for use in environmental programmes.	o Public regulation enforcement failure (vigilance and judicial processes). o Lack of capacities. o Incomplete information. o Communication transaction costs. o Coordination transaction costs.

2.4.5. Gaps in Knowledge

The answers to the questions about the information needed to implement a market valuation of the ES provided by forests at a local level are presented in Box 2.7 to Box 2.10. The questions focused on forest carbon services but also other comments are included for hydrological services and biodiversity.

2.4.5.1. Technical Information to Quantify ES

Technical information is required for valuing ES both at the local and regional levels (Box 2.7). In both cases it is necessary to generate reliable technical information to validate the maintenance or enhancement of ES provided. It is very important to establish a baseline at national and local levels and address the issues of additionality of the proposed activities, as well as to ensure their permanence in the long run and reduce leakage associated with any intervention. Carbon pools include living biomass, but also the soil, so it is necessary to study the dynamics between carbon in soil and associated vegetation. Valuation of hydrological services should be designed to ensure a supply for different types of users (domestic, agricultural and industrial). In the case of biodiversity services, potential uses as well as non-economic value of natural species may be considered for study (i.e. existence value).

Box 2.7 Information needed to quantify ES.

o Study of carbon stocks for different types of vegetation cover (biomass, combustible material/litter, soil) based on existing methodologies (e.g. IPCC), including uncertainty analysis.
o Development of allometric equations, study of carbon content and wood density for different species.
o Biophysical parameters (potential of carbon capture and storage, water availability, habitat necessary to maintain food chains at the municipal level or landscape).
o Relationships between soil characteristics, carbon content, vegetation type, infiltration and run-off.
o Mechanisms for validation and linkage of information obtained in the field and remote sensing.
o Information for baselines, permanence, leakage and additionality of forest management activities / reforestation.
o Assessment of skills and local monitoring requirements for different ES.
o Study of regional wildlife corridors.
o Define the areas eligible for different management practices and their impact on the change of vegetation cover and production of ESs (biodiversity, infiltration, runoff, evapotranspiration, storage of biomass / carbon)
o Identify risks and conflicts between carbon services and biodiversity.
o Interactions between the production of the ESs and other activities (agriculture, industry).
o Identification of traditional uses and potential of the species of wildlife.
o Inventory of species and study of biodiversity indices, species distribution and food chains.
o Analysis of water balance at watershed level considering all users (urban, industrial, agricultural and ecological).
o Identify practices that enhance water infiltration, evaluate quality and availability of the resource.
o Monitoring of availability and quality of groundwater and surface water. Study the dynamics of sediments.
o Classify micro-watersheds according to local climatic conditions and resource availability.

Based on the information requirements identified in Box 2.7, the following questions are posed to explore the quantification of forest carbon services in this research:

1. Based on standard methodologies recommended by the IPCC, what is the estimated carbon stock in biomass in trees in the oak-pine mixed forests in La Primavera?
2. How do carbon stocks vary at different levels of canopy cover?
3. What is the potential production of forest carbon services in La Primavera?
4. What alternatives exist to generate faster and cheaper estimates of carbon content in forest?

2.4.5.2. Provision: Landowners and Communities

Box 2.8 shows the information gaps identified in order to successfully engage rural communities in a mechanism/market to value ES. Participants agreed that, in order to successfully engage landowners, ejidos and rural communities in market mechanisms for valuing ecosystem services, it is necessary to understand the political, economic and social issues and the specific context where projects could be developed. It is important to establish clear and transparent communication with the landowners and members of the ejidos/community. It is also important to know the rules that govern them and understand how decisions are made. An interesting point is the evaluation of how internal conflicts may affect the implementation and success of conservation practices for ES. With respect to economic issues it is necessary to identify the different sources of income and to identify how forest management practices and potential income from PES/market mechanisms could impact the local economy. It is also important to consider the potential funding derived from the valuation of ES within the local context, not only in relation to a possible increased cash flow, but also in relation to other forms of capital that could be present or absent in the community (e.g. Do the communities need public goods or infrastructure? hospitals, schools, roads...). It is very important that landowners/communities are aware of what ES are provided in their territories and are able to engage in collective action if necessary to ensure the compliance of any commitments made in the long run. Academia or NGOs can provide support for the creation of these capabilities.

Box 2.8 Information needed on potential involvement of landowners, ejidos and communities.

o Factors that facilitate participation, negotiation, collaboration and agreements with landowners/ejidos in different regions.
o The needs of landowners/ejidos/communities and how they could be met (education, health, infrastructure, employment, poverty...)
o Local productive options, given local conditions of natural, social and human capitals.
o Options for implementing *ad hoc* or 'tailor made' flexible mechanisms and long-term monitoring of projects by the authorities and project developers.
o Contribution to the assessment of organizational strengthening in support of ESs.
o Potential for effective implementation and adaptation of innovations.
o Potential for integration of different public and private initiatives (e.g. CONAFOR public programs and private markets).
o Options for maintaining clear and transparent communication between the participants including the concept of ESs, and for evaluation of performance of the program, the market, roles and responsibilities, etc. Identification of the role of existing communication mechanisms such as assemblies and magazines / newsletters.
o Ways of promoting the participation of all members (including women and youth).
o Ensuring that owners / communities know the legal framework applicable in their territories and are aware of the ES generated in them.
o Rules for decision making processes and conflict resolution between landowners, ejidos and communities.
o The natural resources needed by communities and the options available to satisfy them (*e.g.* firewood, timber, fodder, water).

Based on the information requirements identified in Box 2.8, the following questions are posed to explore the potential participation of landowners and communities in the provision of forest carbon services in this research:

1. What is the potential for the adoption and implementation of practices aiming to conserve and enhance carbon stocks in biomass in La Primavera and its wildlife corridors?
2. What are the main factors affecting this potential provision?
3. How can an integral approach to enhance environmental services and promote local sustainable development be designed and implemented?

2.4.5.3. Demand: Local Users

To effectively include the users of ES it is necessary for them to acknowledge the use, that is to say, to understand that they have a demand for the ES (Box 2.9). This could be done firstly through campaigns to generate awareness of the link between areas producing ES and their consumption, which for carbon services is primarily in urban areas. An initial step could be taken based on the development indicators such as ecological footprints to define the level of use/consumption of ES and identify those groups that use more/less of them. Voluntary or coercive mechanisms may encourage participation in market mechanisms; these strategies may have different effects on the participation of social actors as well as in economic markets that need to be explored. A policy that should be encouraged is the saving of natural resources and reducing emissions and waste generation since this would reduce the pressure on natural resources. It is important that the government also explicitly recognises its role as a user of ES.

Any system that is designed and implemented should be transparent and verifiable, and there must be a system of public recognition for those participating in market mechanisms for the valuation of ES.

Based on the information requirements identified in Box 2.9, the following questions are posed to explore the potential participation of the users of the ES at the local level focused on the valuation and demand of forest carbon services in this research:

1. Which are the motivators for participation in the valuation of forest carbon services across users in the Metropolitan Area of Guadalajara?
2. What is the capacity and willingness to pay for forest carbon services?
3. How could a valuation mechanism engage local users in an integral approach not only including cash payments?
4. What are the spatial preferences for the valuation of forest carbon services?

Box 2.9 Information on the potential participation of local users of ES.

o Identification of users and levels/patterns of use and access to the ES and options for more efficient use/consumption to reduce pressure on natural resources (e.g. energy consumption, GHG emissions, water consumption and food).
o Awareness campaigns and environmental education to reveal the link between consumers and areas producing the ES they use.
o Motivators to participate and willingness to pay.
o Identification regarding the capacity of the ecosystem in relation to the use / consumption of the ESs.
o Learning from previous experiences, development of pilot projects with the participation of the private sector.
o Potential for in-kind contributions beyond cash.
o Options to provide certainty and transparency in the use of resources, implementation of activities and generation of environmental programs as part of PES and carbon markets.
o Effectiveness of different options in encouraging participation (e.g. tax incentives, cap-and-trade emissions permits, fines for noncompliance, tax deductibility).
o Effective financial management options for the management of resources (e.g. funds, markets, fixed payments, payments per ton of carbon or cubic meter of water).
o Effectiveness and consequences of using different payment rates based on usage/consumption of the ES (e.g. pricing structure similar to drinking water and electricity)
o The effect of environmental certification and public dissemination of private environmental agendas (e.g. use of ES and their contribution to pay the 'ecological footprint').

2.4.5.4. Institutional Framework

Finally, Box 2.10 presents that according to the participants, the institutional framework of a market for ES should include measures to ensure that it is effective and equitable. There should be appropriate legislation to regulate a national market that would require major emitters to reduce externalities. The market should be designed so that the funding is not based solely on the opportunity costs; it should also include implementation and transaction costs. This regulatory framework should be able to integrate the environmental agenda with that of social development (e.g. poverty reduction, gender equality, youth opportunities) according to local cultural and social needs. With regard to economic performance, corruption and speculation in the market should be avoided as far as possible and a minimum price to prevent collapse may be needed. It is also necessary to assess the efficiency of developing separated markets for different ES, or developing only one market mechanism that consolidates all ES. Minimum standards to certify and validate the generation of ES should be defined.

Box 2.10 Information needed on the institutional framework.

o Opportunities to create schemes to promote local capacity/endogenous development, not only paying low opportunity costs, potential for social participation (e.g. women, youth) o Efficiency, effectiveness, costs and benefits of different schemes (e.g. public/private, mandatory/voluntary, scheme for each ES/all services in one market, national/local, payment, time horizon, the mechanism to set prices). o Mechanisms for negotiation of goal setting, compensation of ES including the needs of all stakeholders; mechanisms to reduce speculation and prevent corruption. o Mechanisms for effective implementation, reducing transaction costs and avoiding capture of benefits by intermediaries. o Priority areas for implementation weighing local needs against 'national' needs. o Definition of the legal framework for PES and carbon markets (e.g. laws, standards, standards, certification processes, monitoring, transparency, certainty of long-term monitoring, processes to resolve disputes, stimulation of demand and harmonization with international carbon markets). o Strategies to maximize benefits of existing programs (e.g. ProArbol) which already have domestic funding. o Potential for adaptation of institutions and governance systems, formal and informal (traditions, customs, conventions). o Linkages between institutions and local community governance systems. o Lessons from existing programs; impact from existing programs on the provision of ES, analysis of success factors. o Defining the role of forestry and REDD+ and contribution to the national emissions reductions target; define the role of market mechanisms.

Based on the information requirements identified in Box 2.10 the following research questions are posed to lead this research in the exploration of the institutional framework that could be set for the implementation of local mechanism targeting forest carbon service:

1. How the valuation of reduced emissions from deforestation and forest degradation and carbon sequestration and enhancement could be included?
2. How could an integral scheme to value environmental services and promote participation and rural development be designed and implemented?
3. Considering the carrying capacity of local ecosystems and based on potential demand and supply of carbon services, what could be the role of the forest sector in a local climate change mitigation strategy?

2.4.6. Discussion

Since deforestation and forest degradation are the main processes resulting in the loss of ES of forests, it is necessary to identify the diversity and heterogeneity of the causes and possible solutions. These problems have been well studied in the past. Participants' views agree with statements elsewhere indicating that market mechanisms are not 'silver bullets' for these problems (Engel et al., 2008, page 665). Within the solutions for the four main drivers of deforestation and forest degradation identified during the workshop, market-based mechanisms appeared in those aiming to control land use change; these mechanisms would do little by themselves to promote the efficiency of commercial agricultural and grazing activities or address illegal logging. With reference to problem 1, if the institutional framework to be built to regulate market-based mechanisms for the valuation of ES does not favour coordination in the public sector, this may add more complexities instead of solutions. On the other hand it was acknowledged that measures to increase the efficiency of agricultural production and reduce the use of natural resources in cities and industries would reduce the pressure over natural resources and favour the maintenance of ES.

Many of the solutions identified are already available; however, environmental management faces many failures and distortions produced in the economic and public arenas. Policies and strategies addressing these distortions need to be included in a balanced policy mix to solve these environmental problems, for instance as part of REDD+ (*e.g.* informational and financial failures, perverse incentives, land use and environmental regulations, inclusion of the environmental values in prices or market mechanisms). It will be necessary to implement other activities such as effective legal, judicial and inspection processes along with the supervision and participation of all sectors of society. Moreover, the root causes of deforestation and forest degradation are the demand for land (*e.g.* for housing and touristic development), as well as demand for food and non-timber forest products needed to meet higher levels of consumption in society. Ultimately these processes are strongly associated with population and economic growth; in this context PES/market mechanisms cannot be the only policy instrument needed to guarantee the provision of ES at optimal levels.

Yet market mechanisms and PES will find their niche in environmental policy and as part of the national REDD+ program. For instance, one area for development of these policies corresponds to natural protected areas when conventional economically profitable activities are banned to protect certain ES (e.g. water, biodiversity) and no mechanisms to compensate the landowners for the forgone opportunity costs are provided. Another case concerns areas where forest management offers economically unattractive alternatives to landowners but alternative uses as agriculture or grazing produce very low yields (e.g. tropical dry seasonal forests); in this case the social costs of the ES lost in land conversion may outweigh the marginal local benefits of subsistence activities, which are opening the possibility for development of a compensation system. However, in both cases, enforcement of land use and environmental regulations, and the definition of property rights over the external benefits of ES are necessary pre-conditions for the development of these schemes. Moreover, information on the costs and benefits of ES is required to identify the areas where these mechanisms would work and to define the payment levels.

During the workshop a weak engagement of local users of ES was also perceived; this agrees with the traditional concept of ES as public goods. This was also to be expected in the case of México since the PES program currently operating is predominantly a government program in which most of the incentives are paid through the public budget rather than directly by the users. There are some projects in the voluntary market but these are not yet well known and they are still in their early stages. The disconnection between the direct users of ES in existing market mechanisms also indicates that property rights over the public benefits of the ES are not completely defined yet. As mentioned in Section 2.1, Coase's bargaining example relies on the existence of clear property rights and damage liabilities established in the law (*i.e.* Law of Torts); however, an equivalent definition is not yet in place in México to incentivize users of ES to bargain with landowners/communities to compensate for the environmental damages they generate (*e.g.* GHG emissions). Although the 'polluter pays' principle is integrated into Mexican legislation (Ley General del Equilibrio Ecológico y Protección al Ambiente, LGEEPA, Art 15IV, SEMARNAT, 1988) this has not been used to create responsibility for any environmental cost/damage in this context or promote the demand for forest climatic services. The LGCC defines 'environmental responsibility' as one of its guiding principles indicating that those who develop activities damaging the environment would ultimately have to compensate the cost caused (SEMARNAT, 2012a; LGCC Art. 26 VIII). Although GHG emissions are not yet acknowledged as activities damaging the environment it is likely and probably necessary if demand for forest carbon services in market mechanisms is to be stimulated, that this approach be adopted in the regulations and programs streaming from the LGCC. Property rights are better defined for the supply of ES. The LGEEPA and the recent additions to the General Law for Sustainable Forest Development (LGDFS) recognize the right of landowners/communities providing ES to receive incentives and the economic benefits associated to the ES produced (SEMARNAT 1988, LGEEPA, Art. 15IV; SEMARNAT, 2012b, LGDFS Art. 134bis). A clear definition of property rights on both the supply and the demand side will facilitate the Coasean bargaining among users and providers of ES.

2.4.7. Conclusions

Although the application of market-based instruments for the provision of ecosystem services is attractive because of their apparent efficiency and simplicity, in practice it is hard to reconcile provision of public goods with private markets. The workshop participants repeatedly emphasised the need for public sector organisations and regulatory measures. This highlights the coexistence of conflicting incentives and market and public failures distorting decision making that need to be addressed if market mechanisms are to be used in valuing ES as part of the environmental policy mix. Nonetheless there are specific niches for the development of such schemes, but the informational requirements and transaction costs are far from insignificant and still there is a need to define clear and complete property rights over the benefits of ES and responsibilities for environmental damage. The creation of an institutional framework to enable the exchanges between providers and users is also an obstacle, at least in the short run (Corbera and Brown, 2008). The participants recognise the complexity of creating the necessary institutional framework, the problems inherent to enforcement and monitoring of activities related to valuation of ES. The publication of the LGCC indeed contributes to the formation of an institutional framework for the implementation of these policies. It will be very important that this institutional framework reduces implementation and transaction costs since otherwise efficiency gains of private markets will be hard to achieve. In order to identify the potential areas for implementation and design schemes favouring a successful implementation it will be necessary to generate basic information in a number of areas related to the quantification, provision, demand and regulation of market mechanisms for ES. These activities are vitally important, given that México has adopted a target for reducing 30% GHG emissions by 2020 and that the participation in international carbon markets could increase the domestic costs of climate change mitigation.

3. Methods

3.1. Methodological Approach

Activities in the forestry sector offer an attractive opportunity to contribute to climate change mitigation and adaptation to the negative effects of the inevitable changes that global warming will bring. However, policies implemented for climate change mitigation have not been capable of stimulating the adoption of forest-based mitigation activities at a meaningful scale; this can be observed in the outcomes from the Kyoto Protocol and associated compliance international carbon markets. While forestry-based activities perform better in the voluntary market, their contribution is still very limited. Implementation of REDD+ will have to prove its effectiveness once critical issues relating to financing and demand for mitigation actions through the relevant carbon markets are discussed under the UNFCCC. The increased development of domestic climate policies in developing and developed countries, including the use of market-based mechanisms will require the harmonization of different accounting and trading systems (Sterk and Mersmann, 2011). However, it is not clear yet if local markets will work better to stimulate the implementation of forestry-based activities, and what their role might be in climate policy. It is with the aim of contributing to this area of research that a multidisciplinary approach has been adopted in this thesis to answer the research questions and to try to fill the gaps in knowledge identified in Chapters 1 and 2.

The principal approach used is based on environmental economics, and involves the valuation of forest carbon services by users and providers at the local level; for this a non-market environmental valuation technique (*i.e.* choice experiment or choice modelling) is used to explore the determinants for demand and supply. This analysis requires auxiliary information to define the scale of the carbon services that could be provided by oak-pine forests in México. For this, research methods include forest inventory techniques stemming from IPCC's methodology, in combination with the analysis of satellite images and cartography (IPCC, 2006). The third approach included in the research is related to the definition of the framework for the valuation of carbon benefits under REDD+; for this the advancements in the negotiations of REDD+ under the UNFCCC and basic principles for the design of incentive-based mechanisms are used to analyse the challenges involved in sharing of benefits. The case study, which estimates the flow and valuation of forest carbon services between La Primavera and the metropolitan area of Guadalajara, is used to highlight the potential for local market-based mechanisms that promote both a sustainable rate of emissions and contribute to local development.

The potential and implications of a local market mechanism for forest carbon services are explored from two perspectives. The first approach relies on the standard comparison of the WTP from the potential offset buyers and the WTA of the potential service providers. If the

WTP is higher than the WTA this will indicate that there is room for negotiation of agreements for the provision of forest carbon services and their compensation via mechanisms based on local financing. The willingness of potential buyers (demand) and of potential providers (supply) to participate in offset schemes would imply that climate change mitigation activities would represent a socially desirable scenario. This would further indicate that where climate change mitigation actions are not being extensively developed and where insufficient resources are being channelled to environmental conservation activities, a sub-optimal scenario exists; in the terms of Dahlman (1979), the identification of an alternative scenario in which social actors are better-off would confirm the presence of an externality, reflected by the under-provision of the ES. Nevertheless, it is important to stress that while the WTP has to be greater than the WTA for the development a local market-based mechanism, this is not the only requirement. Exchanges, transactions and/or agreements will take place only if transaction costs can be covered. From this perspective it is critical to identify the policy options minimizing transaction costs. Moreover, the presence of other market and public failures as described in Chapter 2 will have also to be addressed; many of them require solutions different to the standard market-based mechanisms. However, the 'other' market and public failures can be also 'fixed' to enhance the provision of local ES (e.g. by enabling financing access, strengthening law enforcement). Hence, if the results from the environmental valuation exercise indicate that the WTP for mitigation is higher than the WTA, and if the other failures and distortions are addressed, then it would be expected that social actors will implement locally activities that will result in higher climate change mitigation. Given that incomplete information is at the root of transaction costs (Dahlman, 1979) and hence of externalities (Zerbe and McCurdy, 1999), the generation of information associated with the production, costs, benefits and valuation of forest carbon services, is an essential task to evaluate the potential for implementation of local mitigation actions in countries like México.

The second approach to evaluate the potential of local markets for forest carbon services is to consider the carbon balance at the local level, based on the rules for a sustainable rate of emissions (Daly, 1990) framed within the livelihoods approach to development (Carney, 1998); this approach is applied to the case study area of La Primavera and Guadalajara. As described in Chapter 2, the exchanges made in market-based mechanisms for the valuation of environmental services aim to value natural capital and internalize this value into economic transactions. However, the livelihoods approach to development can be used to broaden the scenario, such that these exchanges also have the potential to support local sustainable development.

3.2. Gaps in Knowledge

As mentioned in Chapter 1 (Outline of thesis), the research Chapters (4 to 9) are divided according to four different areas of study identified in relation to the design and operation of market-based mechanisms: quantification, supply, demand and institutional framework. Different approaches and methodologies are used to research specific gaps in knowledge associated with these four areas. Each of the chapters includes a description of the specific methodology used. This section presents briefly a general description of the methodologies used and their relationship with the key gaps in knowledge and the specific research questions in each of the four research areas (Figure 3.1). Figure 3.1 gives a summary of the specific research questions associated with quantification, supply, demand and institutional framework related to the valuation of forest carbon services as presented in Chapter 2.

Figure 3.1 General scheme describing the different elements of market-based mechanisms for the valuation of forests environmental services included in the research and the main research questions.

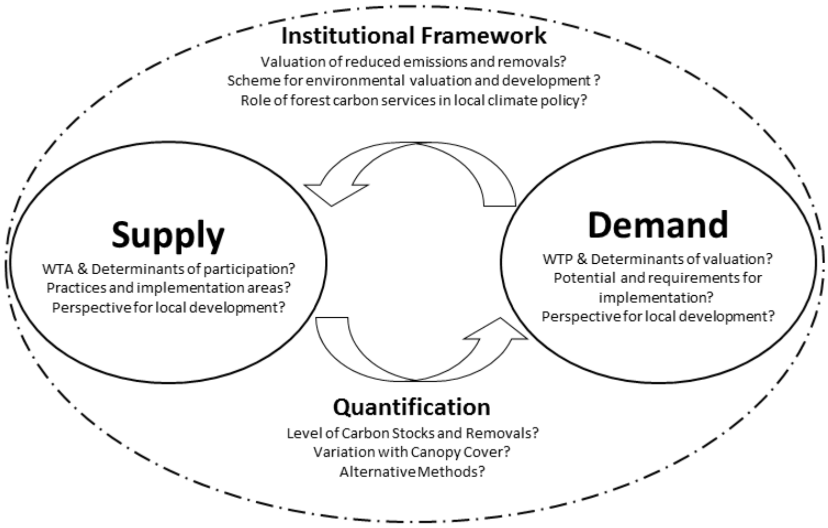


Figure 3.2 Organization of the different chapters of this thesis.

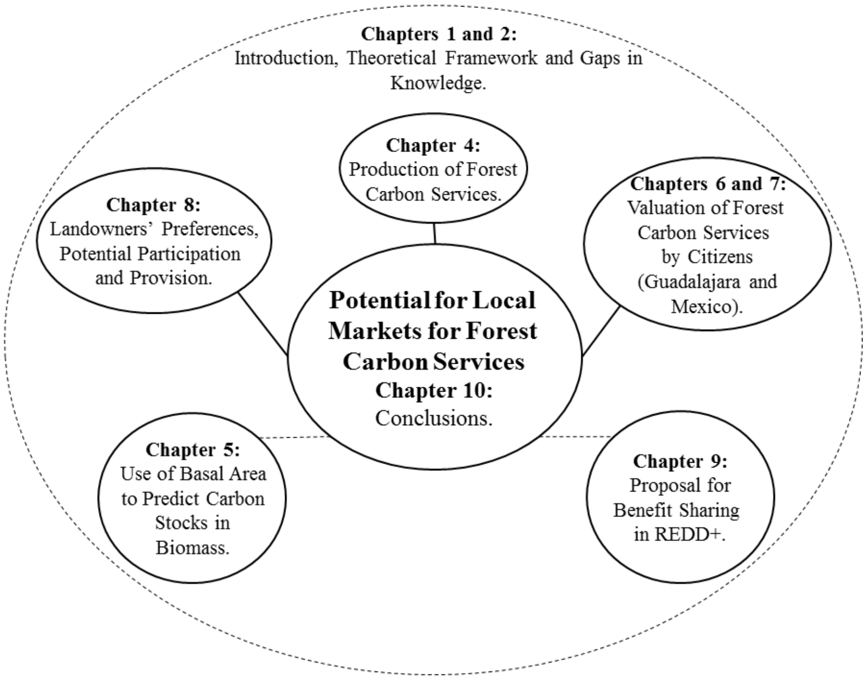


Figure 3.2 shows the contribution of the different chapters to answering the main research question. Chapters 4 and 5 focus on issues related to the quantification of forest carbon services in forests. Chapters 6 and 7 focus the questions related to the valuation and demand of forest

carbon services among Mexican citizens. Chapter 8 focuses on the study of the potential supply of forest ES in the study area. Chapter 9 proposes a pragmatic way of distributing benefits generated under REDD+. As mentioned in Chapter 1, both Chapter 5 and 9 relate to topics that apply equally well to local as to global market-based mechanisms, and are not specific to the case study itself. The following paragraphs describe how the research questions are addressed in Chapters 4 to 10.

3.2.1. Quantification of Forest Carbon Services

The methods to quantify forest carbon services in La Primavera are based on those for the estimation of carbon stocks and stock changes published by IPCC (2006). Since research is developed based on a case study, the analysis is restricted to the prevailing conditions in La Primavera; as described in Chapter 1 this is an oak-pine forest in a dry tropical environment. A forest inventory was undertaken in La Primavera in summer 2009; this was stratified by canopy cover to obtain figures for carbon stocks in areas with different levels of degradation. This is an important feature because canopy cover, the fraction of forest area under the shade of tree canopy, is an instrumental variable related to the threshold for forest (UNFCCC, 2002). This type of information, derived from ground data at this level of resolution, contributes to the understanding of forest degradation and of the potential for forest enhancement. The inventory data consisted of physical measurements of trees to estimate biomass and carbon, using allometric equations and growth functions developed for oaks and mixed forests in México (Návar, 2009; Návar-Cháidez, 2010; Merlín-Bermudes, 2005). In Chapter 4 the results of the forest inventory are used in combination with cartography and processed satellite images to obtain figures on carbon content and potential enhancement and sequestration in La Primavera forest; the potential production of forest carbon services is completed by the estimation reduced emissions from deforestation and forest degradation, which itself depends on the level at which the forest reference emission level is set. The results on stocks and potential removals are compared with the default values published in the IPCC guidelines for the elaboration of national GHG inventories (IPCC, 1996; IPCC, 2003; IPCC 2006) and with nationally derived data (de Jong et al., 2010). In order to explore the potential for reducing the time and cost of generating carbon estimates, Chapter 5 presents an approach based on the use of basal area figures. Basal area is one of the variables most used in the forestry trade for a variety of objectives (particularly in timber management). It has the advantage that it can be quickly and consistently assessed in the field (Piqué et al., 2011). The data from the forest inventory is used in combination with a theoretical analysis of the allometric equations most to explore the use of plot level basal area data to simplify the process of estimating carbon stocks; this under the assumption that any reduction in the cost of generating the information will reduce transaction costs in market-based mechanisms.

3.2.2. Valuation and Demand for Forest Carbon Services

The research questions associated with the potential demand are centred on the study of the main determinants of valuation, the WTP and potential for participation of citizens as offset buyers. Chapters 6 and 7 address these issues. Along with Chapter 8, these chapters make extensive use of results of choice experiments that were set up using choice modelling techniques (e.g. Hoyos, 2010). In order to prevent the repetition, the methodological details are not given here; Chapter 6 presents a detailed description of the assumptions and procedure for the estimation of the econometric models used. As mentioned in Chapter 1 (Thesis Outline) the choice experiments developed in Chapters 6 and 7 permit the evaluation of different conditions influencing environmental valuation; these include the sampling procedure and the way in which the survey was applied and different attitudinal, cognitive and socio-economic characteristics at individual and sample level. The scenario proposed to the participants in the research corresponds to that of voluntary carbon markets; participants were asked to consider the purchase of carbon offsets at different costs and at different project locations. The selected project locations corresponded to three different Biosphere Reserves all located in México: La Michilía in the State of Durango, La Primavera in Jalisco and El Cielo in Tamaulipas (UNESCO, 2011). The main objective of the experiment was to investigate whether or not potential buyers will make their choices based solely on cost-efficiency criteria, i.e. if they would choose only the options offering more offsets at lower cost independent of the project location, or whether they would consider the location and associated co-benefits in their answers. Thus it will be possible to derive evidence as to whether a global carbon market focused on the identification of lowest mitigation options would be the best scheme to mitigate climate change. If on the contrary, locally based mitigation actions were preferred, then responses may provide insights into how these schemes could be designed to motivate participation of local users.

The choice experiment was initially applied in the metropolitan area of Guadalajara, firstly testing three survey application modes, one in-person and two internet based (Chapter 6). Then the same surveying instrument was applied in three different geographical regions in México: the States of Durango and Tamaulipas, population centres aside Guadalajara, and the metropolitan area of México City (Chapter 7); Chapter 7 provides a review of the role that co-benefits of climate policy have in environmental valuation. The surveys in the metropolitan area of Guadalajara were applied between July 2010 and January 2011; the surveys obtained at national level via the market research company were applied from November 2010 to March 2011. The objective of the second part of this analysis was to verify the outcomes from the first experiment in regards to the effect of the inclusion of local project options for the development of forestry-based mitigation actions. Thus, the results from the samples from Durango, Jalisco and Tamaulipas are contrasted with those from the sample in México City in the context of the transfer of benefits (Morrison and Bergland, 2006; Krinsky and Robb, 1986; Poe et al., 2005). Additionally to the results from the stated preference non-market valuation experiment, complementary analyses were undertaken to refine the determinants of environmental valuation. The respondents were grouped based on their responses to attitudinal questions, previous knowledge of personal carbon emissions and revealed data on previous visits to the Biosphere Reserves; this information was used to identify significant differences between them in terms of potential participation in market-based schemes and environmental valuation. This ‘profiling’ helped to identify which groups were more likely to participate in this type of project; this information can help reducing the transaction costs associated with search for a partner to trade-with. It can also help to identify the attitudes, knowledge and experiences that could be promoted among the population to increase the valuation of the environmental services. The Corollary to Chapter 7 presents the potential for implementation and engagement of local users of forest carbon services in Guadalajara, this estimated by identifying the required demand that would 'exhaust' the potential provision of these services in La Primavera. For this, national figures on per capita and corporate GHG emissions are considered jointly with the information on production of forest carbon services presented in Chapter 4.

3.2.3. Supply of Forest Carbon Services

Chapter 8 presents the approach used to estimate the potential provision of forests environmental services, that is, the willingness of landowners and communities to participate and the expected WTA. As mentioned in the previous paragraph a choice experiment was used to gather data to respond to the research questions associated to the supply; surveys were applied between March to August 2011. The identified gaps in knowledge associated with the supply relate to the potential practices that can be developed to maintain and increase the provision of forests carbon services under different land ownership regimes; the identification of factors for and against the participation in incentive-based mechanisms; and the design of an incentive-based scheme which also contributes to local rural sustainable development. The choice experiment was designed to evaluate how landowners and communities owning forest-land (ejidos) would value incentives other than cash payments in PES-like programs. This helped to estimate the WTA and also the valuation of associated local co-benefits enhancing education, health, employment and productive projects in rural areas among the potential providers of environmental services. The survey also included questions exploring the potential for the enrolment of specific tracts of land into these types of schemes including private areas, individual parcels and common use areas in ejidos; the potential adoption of agroforestry practices in cropland; and reforestation of grasslands. The effect of land opportunity costs was also included along with attitudinal questions. The inclusion of the non-cash co-benefits in the experiment allowed understanding of whether or not these would be valuable aspects in market-based mechanisms of this type; the WTA figures help to determine the feasibility of the scheme according to standard economic criteria and the valuation of the co-benefits allows the same type of evaluation using the livelihoods approach to development. If landowners and communities in rural areas value co-benefits which increase local human, social, financial and productive capitals, a broader trading and exchange system could be set between users and providers of the environmental services. The Appendix to Chapter 8 describes briefly how this approach is being implemented in the study area in a project where the findings of this research are being applied; the Corollary to Chapter 8 compares the WTP obtained in the study of the demand to the WTA of the supply.

3.2.4. Institutional Framework and Conclusions

Different elements associated with the design of the institutional framework for local markets for forest carbon services are mentioned throughout the different chapters of the thesis (Chapters 1, 2 and 4 to 8). Chapter 9 presents a proposal for a specific aspect of the institutional framework referring to how the benefits stemming from the valuation of forest carbon services can be shared among different stakeholders. In Chapter 9 the status of REDD+ negotiations under the UNFCCC is used as a starting point to identify the main challenges for benefit sharing. It proposes a system of mixed incentives with one mechanism for the valuation of reduced emissions from deforestation and forest degradation and another for carbon enhancements. One important challenge under REDD+ is how to maintain the integrity of national level carbon accounting and performance while enabling local independent private actors to participate in market-based mechanisms, which may be an important source for financing. Chapter 9 concludes by presenting the implications of the sharing of benefits considering the forest carbon services that can be produced in La Primavera.

Finally in Chapter 10, the main research questions related to the quantification, supply, demand and institutional framework for local markets targeting forest carbon services are revisited, considering the findings of all the research chapters. The final sections of this chapter discuss the implications of developing local markets for forest carbon services in contrast with global markets. The comparison is made in terms of the effect that transaction costs and the valuation of co-benefits of climate policy will have in these two approaches. A summary of recommendations for the design of an institutional framework for local market mechanisms, based on the findings from each research area (e.g. quantification, demand and supply) and their implications for climate policy are presented in the final section of this Chapter.

4. Potential production of forest carbon services in La Primavera, México[7]

4.1. Abstract

Forests contribute to climate change mitigation by removing atmospheric carbon dioxide and storing it in biomass and other carbon pools; additionally appropriate forest management can reduce emissions from deforestation and forest degradation. It is necessary to estimate carbon stocks and stock changes to assess the magnitude and rate of the climatic services provided by forests. To assess the potential production of forest carbon services we used information from a forest inventory stratified by canopy cover in the oak-pine forest of La Primavera Biosphere Reserve in México. Inventory results were used in combination with published allometric equations and a Landsat image to estimate carbon stocks. Potential carbon removals were calculated using published equations estimating tree growth rates, both for enhancements in forested areas and for reforestation/afforestation of non-forest areas. Results are consistent with national figures, previous local research and with the applicable lower-end range default data published by the Intergovernmental Panel on Climate Change. Due to previous forest degradation, mainly from forest fires, carbon stocks are currently below their natural potential. The reference emission level for the estimation of reduced emissions is critical in estimating total forest carbon services. Provided an adequate management plan is executed, carbon removals over 60 to 100 years might be of a comparable magnitude to present carbon stocks in biomass in La Primavera; however, prospects for enhancements in non-degraded areas are limited. If incentive-based mechanisms are used to maintain and enhance forest carbon services, it is necessary to design a balanced mix of incentives and controls to avoid perverse incentives.

4.2. Introduction

Forests contribute to climate change mitigation by removing atmospheric carbon dioxide and storing it in different carbon pools (i.e. biomass, soil, dead organic matter, litter; IPCC, 2006). Deforestation and forest degradation are important contributors to global greenhouse gas emissions but if these processes are addressed, forests can significantly contribute to climate change mitigation. It is estimated that 15% of global greenhouse gas emissions came from deforestation over the period 2000-2005 (Van der Werf et al., 2009). Moreover, forests comprise an important carbon reservoir since they store about twice the amount of carbon present in the atmosphere (Canadell and Raupach 2008). Furthermore, forests could be a potential sink to offset from 2% to 30% of expected emissions during this century (Canadell and Raupach, 2008; Beerling and Woodward 2004). Forest-based strategies are thought to offer a

[7] The material presented in this chapter has been submitted to be considered for publication as Balderas Torres, A., Ontiveros Enriquez, R., Skutsch, M., Lovett, J.C. Potential production of forest carbon services in La Primavera, México.

cost-effective means to mitigate climate change (e.g. Canadell and Raupach, 2008; Strassburg et al., 2009). Appropriate forest management can help both to reduce emissions from deforestation and forest degradation and to increase carbon removals.

Different policies have been devised to promote the conservation and enhancement of forest services. These include programs of payments for environmental services (PES), carbon markets for carbon sequestration and the (as yet not fully agreed) international policy to reduce emissions from deforestation and forest degradation in forests in developing countries (REDD+). These initiatives provide performance-based incentives for the provision of the services. In carbon markets and REDD+ this performance refers to the gains in carbon benefits in reference to a baseline (UNFCCC, 2012c); this creates the necessity to measure and determine the levels and changes in carbon stocks in forests and emissions from forest loss and degradation.

In this work we report the results from a forest inventory to estimate carbon stocks in biomass; this information is used in combination with growth functions to model the potential carbon removals from forest enhancement and reforestation/afforestation; potential emissions reductions from deforestation and forest degradation are estimated for forested areas at different reference emissions levels. The mixed oak-pine forest of La Primavera Biosphere Reserve in México (30,500 ha), is used as the case study. The objective is to obtain an initial estimate of the level of forest carbon services produced in La Primavera as a preliminary step for the valuation of these services. The chapter is divided as follows: first a general description of the methods used to estimate carbon stocks and stock changes are shown; then information about the study area is presented followed by a description of the methods used in the forest inventory and in the estimation of carbon stocks, potential removals and emissions reductions. Finally the results are presented and discussed and some conclusions are drawn.

4.3. Background

4.3.1. Quantification of Forest Carbon Services

The basic procedure for estimating carbon stocks in forests is to obtain an estimate of carbon content per hectare and multiply it by the corresponding area of forest (IPCC, 2006; Maniatis and Mollicone 2010). The Intergovernmental Panel on Climate Change (IPCC) has published methods to assess carbon stocks and stock changes in forests; these methodologies are used in the preparation of inventories of greenhouse gas emissions and to monitor the performance of mitigation measures. They are based on a combination of ground and remotely sensed data (e.g. forest inventories, allometric equations or biomass expansion factors and analysis of satellite images) (e.g. IPCC, 2006). In order to prepare initial estimates, default carbon content figures for different carbon pools are available (Tier 1, under IPCC guidelines); nationally and locally derived data is used to refine the estimates for more advanced assessments (Tier 2 and 3, IPCC, 2003; IPCC, 2006). Forest areas can be obtained from international or national statistics and cartography, ground data (e.g. surveys) and through the analysis of satellite imagery (IPCC, 2006). Changes in carbon stocks can be obtained by performing successive inventories over a period of time to measure net growth, or by the estimation of yearly gains and losses based on growth factors or models and on statistics on rates of extraction (IPCC, 2006). These methods provide the basis for the development of national systems to estimate forest related emissions and removals and activities under REDD+ (UNFCCC, 2010a).

Agreements under the United Nations Framework Convention on Climate Change (UNFCCC) have defined different rules to account for forest carbon services in the context of the provision of positive incentives for their valuation. Carbon removals in new forests are considered carbon sequestration while carbon gains occurring in existing forests under REDD+ are said to be carbon enhancements (additional to gains from reduced emissions from deforestation and forest degradation). In order to separate these two groups of carbon services a clear definition of *forests* is necessary. Forests are defined in the Marrakesh Accords as areas with minimum size of 0.05 to 1 ha where woody plants have the potential to grow at least 2 to 5 m high at maturity and have a minimum canopy cover from 10% to 30% (UNFCCC, 2002). Countries may choose their thresholds within these margins according to their national circumstances. In the Clean Development Mechanism of the Kyoto Protocol (CDM) developing countries can execute reforestation activities in areas that have not been forested since 1990; for afforestation projects the requirement is that the area has not been forest in the last fifty years (UNFCCC, 2002). Thus carbon sequestration activities can be developed in areas which are currently not forests (i.e. cropland, grasslands and degraded land with canopy cover below the threshold for forest). Conversely carbon enhancement and reductions in emissions from deforestation and forest degradation relates to carbon gains in forested areas with canopy cover above the threshold. To enable participation in CDM carbon markets or REDD+ countries need to communicate to the UNFCCC their definition of forests. For afforestation/reforestation projects under the CDM México adopted the 30% threshold for canopy cover, 1 ha for minimum forest area and 4 m for minimum tree height (UNFCCC, 2012d). It is not absolutely certain that these thresholds will be adopted by México in respect of REDD+ (CONAFOR, 2010), but it seems unlikely that they will be changed.

For reforestation and afforestation projects, carbon removals are quantified by comparing the growth of the planted trees with the carbon stock expected according to the business as usual scenario which describes what would have happened had the project not been implemented. Estimations of reduced emissions from deforestation and forest degradation are made on the basis of performance of a project or intervention in comparison with the expected levels of emissions (i.e. in the absence of the intervention) defined in a baseline or reference emissions level (REL). If the baseline integrates also the information on carbon enhancements, then the baseline is referred to as forest reference level (RL) (UNFCCC, 2012c). A major hurdle is the fact that in most cases there is little or no historical data with the required level of detail to set the baselines for forest degradation (Herold et al., 2011). Furthermore there are still no agreed guidelines on how to establish these baselines, although it has been established that countries can prepare their baselines at national and/or sub-national levels (UNFCCC, 2012c). Considering the limited availability of data a number of parties proposed as part of discussions under the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) that at least during the early stages of REDD+, when the systems to monitor forest stocks and changes may not be in place yet, conservative estimates of emissions reductions should be used (e.g.

using Tier 1, default emissions factors or proxies) (SBSTA, 2011a; SBSTA, 2012). At the SBSTA expert meeting on REL/RLs in 2011 there were suggestions in favour of defining default baseline values or proxies for degradation in order to enable its inclusion in the early stages of implementation (SBSTA, 2011b). There were also discussions about whether countries have to choose between a REL or a RL or whether they may develop both, targeting different regions in their countries (SBSTA, 2011b); the decision on RELs/RLs leaves these two options open, but no clear decisions on these matters were taken.

In the case of deforestation, carbon emissions are estimated based on changes in rates of forest loss. For instance if a forest loses 1% of its area per year, the carbon lost will be proportional to the initial stock of carbon in the forest; thus *ceteris paribus* reduced emissions will be higher in areas where forests had initially more carbon. It is important to make clear that under this rationale it is not the level of carbon stocks what will be valued but the change in the rate of loss. However, the level of carbon stocks determines the expected emissions and hence prospects for future reduced emissions, against a given (estimated) risk of deforestation or forest degradation. In the case of forest degradation, the baseline will refer to the annual percentage of carbon being lost from a forest which remains forest (i.e. is not converting to another land use). In this case the potential for reduced emissions from degradation would also be related to the initial content of carbon stocks; more emissions from degradation can be expected in areas with initial higher stocks of carbon, since clearly those areas already degraded could soon reach the threshold for forests/non-forest if the degradation process continues (i.e. they have less carbon to lose). This highlights the importance of evaluating carbon stocks to quantify forest carbon services and the need to account for the level of degradation (i.e. estimation of carbon stocks at different canopy cover levels); the information on canopy cover serves to identify the limit between a forest and a non-forested area for carbon accounting of emissions from degradation and from forest degradation. All estimates of reduced emissions require working with data which are essentially counterfactual (i.e. estimates of what would be the case in the future if the intervention were not to take place), which means they are not fully certain (baselines could be set at different levels, which would result in different assessments of the reductions).

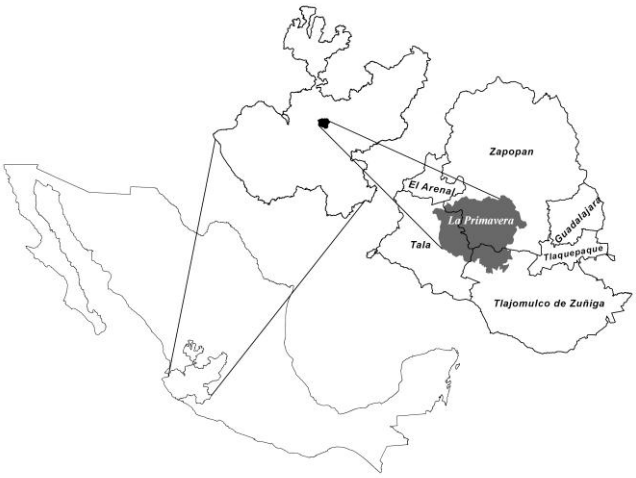
Conversely, carbon enhancements can be readily measured at the local level through standard forest inventories when repeated measurements are undertaken (e.g. Skutsch et al., 2011). Moreover, growth functions of trees can be used to model forest growth and potential enhancements as part of higher Tier methods based on the IPCC methodologies. If a forest area is known to have been degraded or degrading prior to commencement of REDD+ activity, any increases in stock during the REDD+ accounting period will be additional, representing forest enhancement, with the baseline taken as the level of stock measured at the beginning of this period (Skutsch et al., 2011). There will also be a (unmeasured, uncredited) reduction in degradation when the forest enhancement occurs, since the manifestation of growth of stock implies that the degradation has been reversed (Skutsch et al., 2011), hence the estimate of carbon impacts of the REDD+ activity would be conservative.

In this context the objective of this work is to provide an estimate of the potential generation of forest carbon services in the oak-pine forest of La Primavera based on the information from a local forest inventory and published allometric equations and growth functions for this vegetation type. Results are compared with default data provided by the IPCC and national and local data for this type of ecosystems in México. The forest inventory used for the estimation of carbon stocks was stratified by canopy cover to provide a more detailed data on how stock levels in biomass differ in areas with different levels of degradation; the impact of the selection of a particular REL for the quantification of emissions reductions is evaluated.

4.3.2. Study Area

La Primavera forest is a Biosphere Reserve of 30,500 ha and is located in the State of Jalisco in México (Figure 4.1) (CONANP, 2000; UNESCO, 2011). According to its management plan, La Primavera consists mainly of oak-pine mixed forests, but natural grasslands and agricultural areas are also present. The altitude ranges from 1400 to 2200 masl. Annual mean temperature is 20.6ºC (± 6ºC) and annual precipitation ranges from 800-1000mm. Regosols and lithosols are the principal types of soils present; in general, the soil is poor and affected by erosion and recurrent fires (CONANP, 2000). From 1998 to 2012, the aggregate area affected by fires was 29,722 ha (Martinez, 2012), including 8,200 ha which burned in April 2012 (NASA, 2012).

Figure 4.1 Study Area. Location of La Primavera in México, the State of Jalisco and neighbouring municipalities.



According to the IPCC guidelines (IPCC, 1996; IPCC, 2006), La Primavera corresponds to a Tropical Montane System (temperature > 20ºC and altitude above 1000 masl, and would be classified as ‘Dry’ <1000 mm). According to the first inventory of GHG emissions and removals in Jalisco (Alcocer et al., in preparation), preliminary estimates of gross differences in carbon stocks in biomass (not accounting for enhancements and other carbon pools), between 2002 and 2008 in Jalisco are around 1.01% per year[8], while for the municipalities of Tala, Tlajomulco and Zapopan where La Primavera is located, the gross rates of carbon emissions are 2.30%, 2.17% and 1.36% respectively (average 1.84%).

[8] Following IPCC (2006) based on national cartography (INEGI, 2005; INEGI, 2010) for representation of land Approach 3; emission factors at level Tier 2 (de Jong et al., 2010); and statistics on forest fires and timber production (CONAFOR, 2012; SEMARNAT, 2010).

Although no earlier published forest inventory data were available, historical evidence indicates that carbon stocks in La Primavera are decreasing, or at least not increasing. According to La Primavera's management plan, in 1970 the forest area was 25,764 ha, the remaining area corresponding to agriculture, grasslands and bare soil. The forested area decreased to 24,463 ha in 1990 (CONANP, 2000). This change alone represents a loss of 5% of forest area over 20 years (0.3% annually). However, forested areas have also been subject to recurrent fires, most of them associated with human activities (e.g. agricultural practices or even deliberate fires set in an attempt to change land use, El Universal, 2012). From 1998 to 2012, the aggregate area affected by fires was 29,722 ha (Martinez, 2012), including 8,200 ha which burned in April 2012 (NASA, 2012). This is equivalent to 122% of the forested area which means that on average, fires affect 9% of the forested areas per year. Whether these disturbances result in land conversion (e.g. forests to grasslands) and should be accounted as definitive carbon losses (deforestation) depends on the rate of recovery of the affected areas. If affected areas fail to recover to canopy cover levels beyond the thresholds for forest definition in a period of 20 years then they would be reclassified in another land use category and the forest loss would have to be accounted for (IPCC, 2003). However, if areas affected by fires slowly recover to previous biomass stock levels (i.e. above the thresholds for forest definition), fires would not be considered to have resulted in land use category changes or forest loss (instead, the temporary losses would be considered to be degradation), although non-CO_2 emission from fires still would need to be accounted for (IPCC, 2003). If the areas recover but do not reach pervious stock levels thus net degradation, emissions could be estimated.

4.4. Methods

4.4.1. Forest Inventory

The forest inventory focused on measurement of trees in oak-pine mixed forests; 103 measurement plots of 30 x 30 m were established between June-July 2009. Variables measured included diameter at breast height (DBH, at 1.3m), total height, height to the base of living crown and crown diameter. All trees with DBH larger than 7.5 cm were measured, sprouts bifurcating below 1.3m height were considered as individual trees. Basal area was obtained by summing cross sectional area at breast height for all trees in the measurement plots; site slope was measured with a clinometer. Sites were located over areas with slopes of less than 65%. Canopy cover was obtained by mapping the shade contour of the crowns of the trees present in the plot and then computing the area covered by them (Gill et al., 2000). Sampling was random and stratified for three levels of canopy cover: low (10-30%), medium (30-60%) and high (>60%).

4.4.2. Allometric Equations and Growth Models

Biomass in trees was estimated using the equations for below and above ground biomass for pines and oaks, as published by Návar (2009) (Equations 4.1 and 4.2). These equations were developed in north-western México in oak-pine forests with similar soil and precipitation conditions to those of La Primavera; these are considered to be the best available published allometric equations for biomass for our case. Biomass figures are converted to carbon assuming biomass has 50% carbon content and to CO_2 using the factor (44/12) (IPCC, 1996). In Equation 4.1 the specific gravity (ρ) for oaks is 0.63 and for pines is 0.55 (Návar, 2009).

$$Aboveground\_biomass = 0.0752 * DBH^{2.4448} * 2.0031^{\rho}$$ Equation 4.1

$$Belowground\_biomass = 0.0051 * DBH^{2.668}$$ Equation 4.2

Based on the National Forest Inventory, Návar-Cháidez (2010) indicates that the productivity (growth rate) in mixed oak-pine forests in Nuevo Leon, north-eastern México is low, with an average diametric increment of less than 0.36 cm/year. Merlín-Bermudes (2005) studied the growth of oaks in the state of Durango, and presents figures for the growth of *Q. sideroxyla* Humb & Bonpl which are also low (< 0.30cm/year), indicating that oaks may reach diameters of 20 cm only after 150 years. The DBH-age growth model presented by Merlín-Bermudes (2005) is used to derive the equation for the yearly diametric increment for oaks as function of current DBH (Equation 4.3). Equation 4.4 gives the annual growth rate of mixed pines and oaks based on observations of the time, required for a 5 cm increase in DBH, given different starting DBHs based on information of Návar-Cháidez (2010). Increments in Equations 4.3 and 4.4 are given in cm/year. For each tree in the inventory, we calculated the potential increment based on the initial (measured) DBH and the yearly increase over a given period of time, using the growth model of Merlín-Bermudes for the oaks and the growth rate observations of Návar-Cháidez for the pines.

$$Increment\_Oaks = 0.1184 * \ln(DBH) - 0.1036$$ Equation 4.3

$$Increment\_Pines = 1.1384 * DBH^{-0.47}$$ Equation 4.4

Based on Equations 4.3 and 4.4 the increments in DBH of the trees measured in the inventory are obtained for periods of 5 years up to 30 years and then for a period of 30 years (60 years from present) and a final period of 40 years (100 years from present). Based on the final DBH at the end of each period, Equations 4.1 and 4.2 are used to estimate the new carbon stock and enhancement for 30, 60 and 100 years for each tree and at the inventory plot level; final basal area (m^2/ha) at the end of each period is also calculated. Enhancement also includes the growth of new trees recruited in the areas without canopy cover; this growth modelling assumes a zero mortality of trees in each plot. When the value of basal area or carbon content in a plot reached 40 m^2/ha and 625 tCO_{2eq}/ha respectively, no further enhancements were allowed in the calculation, to prevent the estimation of values above the maximums registered in La Primavera. The potential for carbon sequestration in non-forest areas is estimated using Equations 4.3 and 4.4 and for a reforestation plan of 300 oak and 400 pines per hectare.

4.4.3. Forest Area

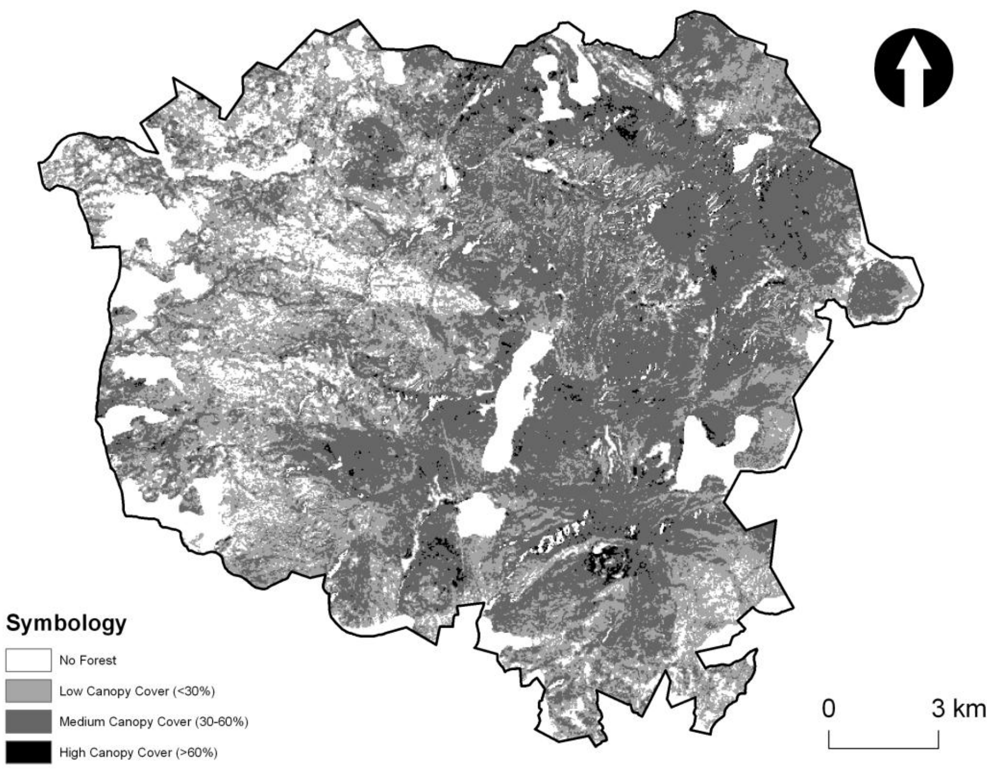
In order to generate carbon estimates for La Primavera, forest area was estimated from local cartography in combination with the analysis of recent mid-resolution satellite imagery (Landsat from March 2011). The use of Landsat images has been suggested by some parties for the first stages of REDD+ since it provides information over relatively long time span (from 1990 to

2005) and is freely available (SBSTA, 2011a). A Landsat L5 scene from 01-Mar-2011 (pixel resolution 30m) was classified through the algorithm published by Palacios-Sanchez et al., (2006)[9]. This algorithm classifies pixels as bare earth, vegetation with low (10 to 30%), medium (30-60%) and high cover (above 60%) and other classes according to its spectral signatures (Paz-Pellat et al., 2010).

Suitable Landsat scenes close to the time of the inventory were unfortunately not found; requirements were that they should cover the whole area, be relatively cloud free and have been taken in the same months as the inventory. The scene from March 2011 was selected because no major forest fires were reported between the time of the inventory and the date of the satellite image and it was the one closest to the dates in which the inventory was done. The most recent large fire before the inventory occurred in 2005 and affected about 11,000 hectares in the western part of La Primavera (Martinez, 2012).

The Land Use and Vegetation Map Series IV (INEGI, 2010) of the National Institute for Geography and Statistics (INEGI) was used as a mask to identify oak-pine forested areas; INEGI Series IV is based on 2007-2008 SPOT images with field verification from 2006-2007 (Victoria-Hernandez et al., 2011). Using INEGI's polygons the pixels inside the forest area were then classified as non-forests (i.e. bare earth) or according to the vegetation cover level taken from the Landsat image (low, medium and high) (Figure 4.2).

Figure 4.2 La Primavera, Landsat 5 image classified by canopy cover level.



[9] The author is grateful to Dr. Fernando Paz Pellat, Martin Bolaños, and Edgardo Medrano from COLPOS for the help in the classification of the image following the algorithm by Palacios-Sanchez et al., (2006).

4.4.4. *Tier 1 and 2 Values for Carbon Stocks and Increments in Oak-Pine Forests*

Carbon content in forests varies across ecosystems, and with management practice and the degree of conservation. In the case of oak-pine mixed forests, default above ground biomass factors range from 94 to 204 tCO_{2eq}/ha (IPCC, 1996) [10]; and from 140 to 540 tCO_{2eq}/ha for the mountain tropical climatic region in the most recent guidelines (IPCC, 2006)[11]. These values correspond to Tier 1 level emission factors. Carbon content figures based on the national forest and soil inventory (Tier 2 data), are 150tCO_{2eq}/ha (uncertainty, U= 6%) for primary and 66 tCO_{2eq}/ha (U=14%) for secondary mixed forests (de Jong et al., 2010). Using the land cover classes from INEGI (2010), the mean weighted value for carbon content in La Primavera, based on the national data published by de Jong et al., 2010 is 149 tCO_{2eq}/ha (142-157 tCO_{2eq}/ha, 95% C.I., U=5%).

Basal area is also often used as a proxy for biomass and carbon content (e.g. Philips et al., 1998). In a local study developed in the Rio Salado watershed which accounts for 40% of the area of La Primavera, the basal mean area was found to be 12.6m^2/ha and was positively correlated with canopy cover as estimated from aerial photographs (Santiago-Pérez and Villavicencio-García, 2007). In the work presented here however, the forest inventory covers the whole of the Biosphere Reserve and takes into account variations in canopy cover as measured from the ground, and this is used to derive carbon content in arboreal biomass, with the help of published allometric equations. The default and the national and local published values are then compared with the results of the forest inventory.

The IPCC default values for annual biomass growth in Tropical Mountain Systems and vegetation types most similar to those of La Primavera are presented in Table 4.1. In the IPCC guidelines these values are used to estimate carbon removals by biomass growth in forested areas for the purposes of national GHG inventories. According to de Jong et al., (2010), in secondary (abandoned) mixed oak-pine forests biomass increment during 1993-2002 was 1.1 tonnes of biomass/ha-yr (0.9-1.3 tonnes of biomass/ha-yr, 95% C.I.).

Table 4.1 Default values for annual biomass growth factors in IPCC guidelines.

Source	Climatic Domain and Vegetation Type	Annual Growth (ton/ha-yr)*
IPCC, 2006	*Natural Forests in Tropical Mountain Systems*	
	North and South America (<20yr)	2.0 -6.4
	North and South America (>20yr)	0.6 - 1.9
	Plantations in Tropical Mountain Systems	
	Americas *Pinus*	12.7
	Americas Other Broadleaf	5.2

*Annual growth of aboveground biomass taken from IPCC (2006) belowground biomass is added based on the equation for belowground biomass published by Cairns et al., (1997) BGB=exp(-1.0587+0.8836*ln(AGB)).

[10]Default values for this vegetation type refers to Table 5.5 and 5.6 in the workbook IPCC (1996), belowground carbon is estimated using 0.28 as below to aboveground biomass ratio.
[11]Default aboveground biomass values from Table 4.7 in IPCC (2006), considering a 0.27 and 0.29 ratio of below to aboveground biomass respectively from Table 4.4 also in IPCC (2006).

4.5. Results

4.5.1. Forest Inventory and Carbon Stocks

The general results of the inventory at the plot level are presented in Table 4.2; 3,412 trees of 14 species were measured (oaks (9 species), pines (2) and other genera (3)). The dominating species were *Q. resinosa* Liebm. and *P.oocarpa* Schiede ex Schltdl.

Table 4.2 General Characteristics of the Forest Inventory at plot level.

Variable	Mean	S.D.	Range
Basal Area (Inventory) (m^2/ha)	17.0	7.5	1.9- 37.0
Weighted Mean Basal Area (m^2/ha)[a]	12.5	3.7	11.7-13.3[b]
Canopy Cover (%)[c]	54%	22%	10- 96%
Density (trees/ha)	368	280	11- 1,144
Mean D in site (cm)	27.3	15.8	14.7- 158.0
Mean Crown Diameter in site (m)	6.3	4.4	1.9- 36.3
Mean Height in site (m)	12.2	4.3	3.6 - 35.9
% of Oaks	62%	30%	0- 100%
Slope (%)	12.0%	9.3%	1.0- 60.0%
Altitude (masl)	171	197	1410- 2180

[a] Weighted stratified mean and S.D. according to forest area under each canopy cover class. Stratified mean and variance computed following standard statistical methods in Schreuder et al., 2004.
[b] Corresponds to 95% C.I. based on the standard error of the stratified basal area (IPCC, 2000).
[c] Canopy cover maps were drawn in 90 sites.

Table 4.3 shows the carbon content per hectare and the 95% confidence intervals obtained in the inventory for mixed forests with low, medium and high canopy cover levels.

Table 4.3. Carbon content in arboreal biomass (tCO_{2eq}/ha).

Strata		Mean (S.D.)	Range (95%)	S.E.	C.I. (95%)[a]	U.	n
Canopy Cover (C.C.) (%)	Low C.C. < 30%	130 (63)	59 258	17	92 168	29%	13
	Med. C.C. 30-60%	199 (77)	93 371	12	175 222	12%	43
	High C.C. > 60%	336 (120)	161 624	21	293 379	13%	33

[a]Based on the standard error of the means (IPCC, 2000), and using the t-values for two tailed 95% C.I.

The weighted mean for carbon is 170 tCO_{2eq}/ha (160-181tCO_{2eq}/ha, 95% C.I, U=6%). Table 4.3 shows the differences in carbon stocks for forest areas with different canopy cover levels.

There is no overlap in the confidence intervals of the three types of areas showing the differences in carbon stocks at different levels of canopy cover. However, it can be noticed that the uncertainty for the areas with low C.C. is larger due to the smaller sample size. Considering the size of the inventory plots chosen, the incidence of areas with low canopy cover levels was lower (i.e. when there were few trees these tended to be large thus easily covering more than 30% of the plot). This could have been solved if we had used larger plot sizes for the low canopy cover class, however, the plot size was held constant to keep the consistency across the three canopy cover classes. Nevertheless, the differences in the level of carbon stocks indicate the general trend in carbon loss that can be associated to forest degradation measured as reductions in canopy cover. Table 4.4 presents the carbon content in La Primavera obtained by multiplying the area of each cover class by the corresponding carbon content.

Table 4.4 Carbon content estimate in arboreal biomass in oak-pine mixed forest in La Primavera (Mean values, and 95% C.I, values in $MtCO_{2eq}$)

Canopy Cover Class	Area (ha)	Mean (Min.-Max.)
Low C.C.	10,605	1.38 (0.98-1.78)
Med. C.C.	13,442	2.67 (2.35-2.98)
High C.C.	324	0.11 (0.09-0.12)
Total	***24,371***	***4.16 (3.42-4.89)***

Min/Max according to the 95% C.I. in Table 4.3, Non-forest area 6,265 ha.

4.5.2. Carbon Removals

Table 4.5 presents the biomass growth rates expected in La Primavera forest, by areas of different initial canopy cover, together with the potential carbon sequestration from reforestation in non-forested areas (lower part of the table).

Table 4.5 Biomass growth rates and expected basal area in La Primavera (mean values, and 95% C.I.)

Change Described	Mean Biomass Growth Rate (ton/ha-yr)			Basal Area (m^2/ha)			
	0 to 30 years	30 to 60 years	60 to 100 years	Initial	30 years	60 years	100 years
Enhancement Forest Areas							
Low C.C.	1.7 (1.0-2.4)	2.1 (1.4-2.7)	2.0 (1.2-2.8)	9.4 (6.3-12.6)	15.9 (9.5-22.2)	21.4 (15.6-27.3)	29.6 (23.6-35.5)
Medium C.C.	2.8 (2.5-3.2)	2.3 (1.8-2.8)	0.4 (0.2-0.7)	14.0 (12.5-15.5)	23.6 (21.0-26.1)	33.5 (30.6-36.5)	40.0 (37.7-42.3)
High C.C.	3.2 (2.4-3.9)	0.2 (0.0-0.4)	0.1 (0.0-0.3)	23.7 (21.5-25.9)	37.0 (34.3-39.8)	38.8 (37.1-40.6)	39.6 (38.9-40.2)
Reforestation/ Afforestation							
Oaks (300 trees/ha)	0.04 (0.03-0.06)	0.12 (0.09-0.14)	0.5 (0.4-0.6)	-	0.4 (0.3-0.5)	1.2 (0.9-1.6)	4.7 (3.5-5.8)
Pines (400 trees/ha)	1.23 (0.92-1.54)	2.47 (1.85-3.09	3.6 (2.7-4.5)	-	7.2 (5.4-9.0)	17.6 (13.2-22.0)	34.5 (25.9-43.5)
Total Reforestation/ Afforestation	1.27 (0.96-1.59)	2.58 (1.94-3.23)	4.1 (3.1-5.1)	-	7.6 (5.7-9.5)	18.8 (14.1-23.5)	39.2 (29.4-48.9)

As mentioned earlier, the inventory information was used to set a limit to potential growth of trees. We consider that it is unlikely that forests can reach values greater than 40 m^2/ha for basal area and 625 tCO_{2eq}/ha for carbon content since these were the maximum values found during fieldwork. For this reason, in the forest areas with high canopy cover, growth falls from year 60 onwards as most sites will have reached basal area above 35 m^2/ha. For the case of reforestation, considering the slow growth rates implied by equations 4.3 and 4.4, it is clear that it will take longer for oaks to grow and capture carbon and reach their maximum biomass (100-200 years); this is reflected in the fact that after 30 years the expected basal area for this reforestation plan will be relatively low (<8 m^2/ha). The estimated basal area figures after 100 years for areas with medium and high C.C. and for afforestation/reforestation are considerably higher than the basal area values measured during the inventory; this indicates that the predicted increments in stocks over long time horizons may not be realistic given the limits on growth imposed by soil quality and disturbances (e.g. fires).

Table 4.6 shows the potential for carbon enhancement in forest (natural increases due to growth once forests are better protected) and carbon sequestration (in new plantation of trees) in La

Primavera. The table includes the potential enhancements at 30, 60 and 100 years. Over a 100 year horizon it can be seen that potential carbon removals would be higher than the current levels of carbon stocks in aboveground biomass (e.g. mean values 11.21 vs. 4.16 $MtCO_{2eq}$). However, as presented in the Table 4.5, to reach the levels suggested in the 100 horizon, the forest would have to grow to basal areas higher than those observed in any of the measurement plots. For this reason, the scenario for potential carbon removals is restricted to the actual maximum basal areas observed in the field inventory (last column in Table 4.6). In this scenario it is assumed that areas with high canopy cover level are already in equilibrium, thus further enhancement would not be expected. Areas with low canopy cover and those afforested/reforested would grow up to the value presented for the 60 years horizon with mean basal areas of 21.4 and 18.4 m^2/ha respectively; enhancements in areas with medium canopy cover would be those corresponding to a horizon of 30 years, with mean basal area of 23.6 m^2/ha. Under the restriction imposed by current maximum basal area, the potential carbon removals will be still of higher magnitude than current carbon stocks (5.61 vs. 4.16 $MtCO_{2eq}$), meaning that in the long run (60 years) there is the potential to double the standing stocks in La Primavera.

Table 4.6 Potential for carbon enhancement and sequestration in arboreal aboveground biomass in oak-pine mixes in La Primavera ($MtCO_{2eq}$).

Carbon Enhancement/ Removals	30 years	60 years	100 years	Scenario Restricted by Basal Area
Enhancement in Existing Forests				
Low C.C.	*0.99 (0.58-1.40)*	2.22 (1.40-2.97)	3.77 (2.33-5.15)	2.22 (1.40- 2.97)
Medium C.C.	*2.07 (1.85-2.37)*	3.77 (3.18-4.44)	4.16 (3.38-5.13)	2.07 (1.85-2.37)
High C.C.	*0.06 (0.04-0.07)*	0.06 (0.04-0.08)	0.06 (0.04-0.08)	-
Sub-Total Enhancement	3.12 (2.47-3.84)	6.05 (4.62-7.49)	8.00 (5.75-10.36)	4.29 (3.25-5.34)
Sequestration in non-Forest areas Afforestation/ Reforestation	0.44 (0.33-0.55)	1.33 (0.99-1.66)	3.21 (2.41-4.01)	1.33 (0.99-1.66)
Total Potential Removals (Enhancement + Sequestration)	3.56 (2.80-4.38)	7.37 (5.62-9.15)	11.21 (8.16-14.37)	5.61 (4.24-7.00)
Total Potential Carbon Stocks (Actual + Potential Removals)	7.72 (6.22- 9.27)	11.53 (9.04-14.04)	15.37 (11.58-19.26)	9.77 (7.66-11.89)

4.5.3. Reduced Emissions and Total Forest Carbon Services

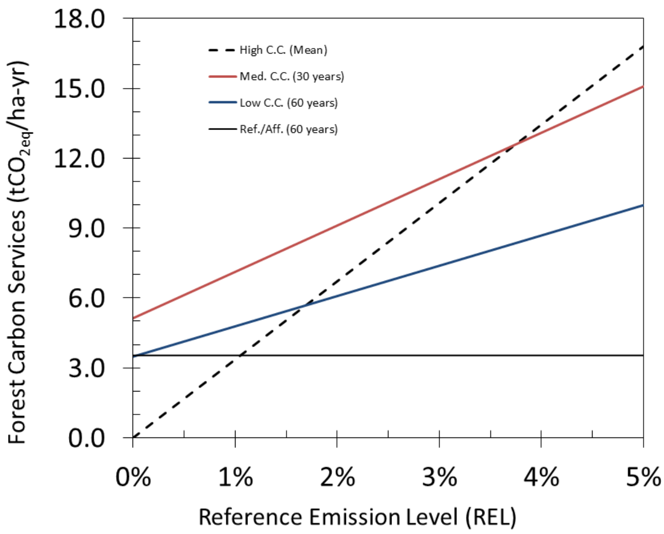
Results in Table 4.5 and Table 4.6 indicate the potential magnitude of carbon enhancements that could potentially be reached under programs offering incentives through valuing forest carbon services (e.g. PES, voluntary carbon markets or REDD+). To fully estimate the potential carbon gains from improved forest management in La Primavera, it will be necessary to include potential gains from emissions reductions. Although the REL will (eventually) be set as part of national or sub-national REDD+ activities, it is possible to evaluate how RELs set at different levels would influence the quantification of forest carbon services. Based on information on carbon stocks and potential removals, Table 4.7 shows the scale of potential reduced emissions and total forest carbon services in La Primavera at two different RELs (1.0% and 3.7%); average yearly values are obtained over the relevant time horizons.

Table 4.7 Potential forest carbon services from reduced emissions and removals in La Primavera. All values in tCO_{2eq}/ha-yr and correspond to the mean, and minimum and maximum values (95% C.I.)

	Forest Areas			Reforestation/ Afforestation (60 yrs.)
	Low C.C.	**Med. C.C.**	**High C.C.**	
Reduced Emissions, REL=1.0%	1.3 (0.9 – 1.7)	2.0 (1.7 – 2.2)	3.4 (2.8 – 3.7)	-
Reduced Emissions, REL=3.7%	4.8 (3.4 – 6.2)	7.3 (6.5 – 8.2)	12.6 (10.3 – 13.7)	-
Carbon Removals	3.5 (2.2 – 4.7)	5.1 (4.6 – 5.9)	-	3.5 (2.6 – 4.4)
Total Forest Carbon Services, REL=1.0%	**4.8 (3.1 – 6.3)**	**7.1 (6.3 – 8.1)**	**3.4 (2.8 – 3.7)**	**3.5 (2.6 – 4.4)**
Total Forest Carbon Services, REL=3.7%	**8.3 (5.6 – 10.9)**	**12.5 (11.1 – 14.1)**	**12.6 (10.3 – 13.7)**	**3.5 (2.6 – 4.4)**

Table 4.7 shows that given the higher initial level of carbon stocks, potential emissions reductions will be higher in areas with higher levels of C.C. However, if management of areas following degradation processes is successful and enhancements are produced, this would imply that because an unknown rate of degradation has been reversed, carbon gains measured in terms of enhancement alone will underestimate climate benefits (Skutsch et al., 2011). Thus total forest carbon services can be obtained by the aggregation of potential removals plus emissions reductions. At a REL of 1.0%, total carbon gains in areas with high C.C. (in equilibrium) will be lower than those for areas with low and medium C.C. and even slightly lower than those for reforestation/afforestation activities. In this case only when the REL is equal to 3.7% will carbon gains in areas with high C.C. match those of medium C.C. at mean values. Figure 4.3 presents a graphic representation of the changes in the aggregated forest carbon services in areas under degradation, or at risk of deforestation, as function of the REL. This demonstrates how for lower REL values, potential carbon gains are lower in areas in equilibrium; for reforestation/afforestation, potential carbon benefits are independent of the REL.

Figure 4.3 Potential forest carbon services in La Primavera as function of the REL (considering mean values for carbon stocks and potential removals).



4.6. Discussion

4.6.1. Comparison with Default Values and Local Studies

The estimates of carbon stocks obtained in this study are within the range of the default values provided by the IPCC and are also consistent with published information in México for this type of vegetation. The weighted mean for carbon stock is closer to the higher end of the range of default values for this vegetation type as first published by IPCC (1996); however, it is very close to the lower limit of the range of the values published in IPCC's more recent guidelines (IPCC, 2006). Estimates of carbon stocks are higher than those presented by de Jong et al., (2010) (i.e. mean value 149 tCO_{2eq}/ha as described above). However, this is partly due to differences in the allometric equations used; de Jong et al., (2010) used the equations published by Brown (1997) and Cairns et al., (1997) because they generate the most conservative values (please refer to de Jong et al., 2010, page 1699). If these equations are applied to the inventory data presented here, the weighted average value for carbon in biomass becomes 141 tCO_{2eq}/ha (133-149 tCO_{2eq}/ha, 95% C.I), which is even lower than the estimate based on the national estimates by de Jong et al., of 149 tCO_{2eq}/ha (142-157 tCO_{2eq}/ha, 95% C.I).

The results of the forest inventory are also similar to estimates of level of stock published earlier for La Primavera, expressed in terms of basal area. The weighted basal area found here is in agreement with the figure found in the Rio Salado watershed by Santiago-Pérez and Villavicencio-García (2007) (i.e. 12.5 m^2/ha vs. 12.6 m^2/ha). However, the basal area for the high C.C. areas, 23.7m^2/ha (21.5-25.9m^2/ha, 95% C.I.) is higher than the 18.5 m^2/ha for the class with high canopy cover in Rio Salado although there is an overlap of the confidence intervals (14.8-22.3m^2/ha, 95% C.I., C.C.>75%[12]). Something to consider in explaining this is that the largest trees found in the inventory presented here were *Q. castanea* Née, and this species is not reported for the study in Rio Salado. The sampling of areas outside Rio Salado watershed and at higher altitudes where larger trees were present increased the basal area values for this canopy cover class in our forest inventory.

The biomass growth rates presented in Table 4.5 are similar to those reported in the IPCC guidelines for natural forests (Table 4.1): they are at the higher end of areas older than 20 years and the lower end limit for younger forests (<20 years). They are well below the values reported for plantations for this climatic domain. When differences due to the selection of the allometric model are considered, the growth figures are also within the range provided by national data. The general agreement in the results of the local data with that obtained at national level indicates that there were no biases during the sampling and thus results for different canopy cover levels can help to set reference values for stock levels in degraded areas.

If default values are to be used to generate conservative figures of carbon stocks and potential enhancement in this type of vegetation and climatic domain, one recommendation is to select values closer to the lower end of the ranges provided by IPCC; otherwise it is likely that default

[12]Santiago-Pérez and Villavicencio-García (2007) present the mean, CV and n; the C.I. presented here is estimated by the authors based on the published data and deriving the standard error of the mean and using t values (95%, 2 tailed). U corresponds to half the width of the C.I. based on the standard error divided by the mean (IPCC, 2003).

values would overestimate carbon content and enhancement figures especially in degraded areas. This issue is relevant because as mentioned above, it may be necessary to use default data to make estimates of carbon stocks and stock changes in REDD+ at least during the first stages of implementation. In this context it is necessary to define what is meant by 'conservative' estimates. Usually conservative estimates refer to values that lie below the real ones. However, the IPCC default carbon content values refer to undisturbed areas of forest (SBSTA, 2011a); thus when default factors are used in forest areas that have been degraded or that have a lower carbon density or canopy cover than intact forests, carbon content and subsequent emissions/removals may in fact be overestimated. Moreover, if default values are going to be used to estimate potential enhancement over long periods of time, it is necessary to determine the higher end limit for enhancements, as we have demonstrated, using the locally observed values for basal area; failing to set a limit when growth is modelled over a large period of time may result in unrealistic estimates of potential stock levels, i.e. above those that can be observable in reality. The careful selection of appropriate allometric models is indeed one of the most important aspects to be considered in assessing carbon stocks, since differences between equations is one of the largest contributors to the uncertainties of the estimates (Van Breugel et al., 2011; Chave et al., 2004).

4.6.2. Potential Production of Forest Carbon Services

The values for potential carbon removals presented here are based on the modelling of tree growth. Although these are similar to default and nationally derived values, it is still necessary to evaluate if improved forest management in La Primavera including control of fires, grazing, soil improvement and fertilisation would lead to carbon stock increases of the magnitude estimated. Field measurements over time in pilot areas under such management would be needed in order to assess impacts of management improvements in terms of annual growth rates of stock. It is important to recall that the estimates presented here only considered one of the carbon pools (i.e. biomass in trees, above and below ground). If other carbon pools and emissions from forest fires and other disturbances are factored in, the potential enhancement and emissions reductions from sustainable management of La Primavera could be even higher. Given the faster growth of pines, including a higher proportion of pines in the mix would increase the initial rate of carbon capture over the first 100 years after reforestation. In many areas the presence of pines has been reduced precisely because of their higher vulnerability to the frequent fires; in this sense the oaks have a competitive advantage as they have a great facility to produce new sprouts when the stem has died in the fire, provided the root is not affected (e.g. Zavala-Chávez, 2001). If carbon sequestration is to be included as an element of the management plan in La Primavera the advisability of reintroducing pines (*P. oocarpa*) in areas where it has presumably been displaced by frequent forest fires should be carefully considered. If increasing the densities of pine is adopted as part of forest management plan, any thinning that takes place in the future should be considered as a carbon loss (degradation) unless carbon storage in durable wood goods can be demonstrated.

The second point to consider in the quantification of forest carbon services in La Primavera is the way in which climate change mitigation benefits from reduced emissions will be quantified. In this context the level at which the REL is set will play a crucial role as indicated above. There is a real danger of perverse incentives and moral hazards associated with this since compensation would be potentially higher to those who had previously deforested/degraded forests than to those with better previous performance (e.g. Wunder, 2009). Adequate and effective policy instruments to control and incentivize reduction in emissions from deforestation and degradation and conservation of carbon stocks in forests should be considered (see also Chapter 9 for a means to avoid these kinds of perverse incentives).

In practice, in order to promote carbon enhancements and sequestration the essential first step is to address the issues associated with carbon emissions (e.g. fires and deliberate land use change); recurrence of human induced disturbances can compromise permanence of carbon gains. If activities to increase carbon stocks are to be implemented in La Primavera, then additional issues that need to be considered in estimating forest carbon services are the permanence and risks arising from future disturbances and the potential leakage from displaced agricultural and grazing practices.

4.6.3. Further Work

It may be noticed that the area of forest in La Primavera with high canopy cover, as derived from the Landsat image is quite small (Table 4.4). This may indicate the degree of degradation of the forests; however, it could also indicate systematic differences in the methods used to assess canopy cover. In the canopy maps drawn during fieldwork the crowns were considered 'solid', which results in an overestimation of canopy cover in comparison with the estimates made from the satellite image. The remote sensor detects soil and signals of other non-photosynthetic materials through the spaces within the canopy; this produces a conservative result for forest area under each forested canopy cover class. An alternative could have been to select a scene corresponding to the rainy season when the foliage would have been denser; however, grasslands and seasonal vegetation might then have been interpreted as aerial vegetation (Paz-Pellat et al., 2010), thus resulting in overestimation of canopy cover, forest area and carbon stocks. In trying to reduce this problem, the Series IV of INEGI was used as a mask to identify forest and non-forest areas and then subtract pixels classified as bare land to refine the value for forest area. An alternative approach would have been to determine on the ground the factor of 'light porosity' of tree crowns, and thus develop a factor to reduce the canopy cover levels measured during fieldwork by a given percentage; this would have most likely resulted in the increase in estimated carbon stocks for the lower canopy cover classes since some plots in the inventory which were identified with higher cover and carbon, would have changed classes. The problem of describing changes in canopy cover accurately and precisely is one of the well-known limitations in the use of mid-resolution imagery for detailed studies of degradation and enhancement in forests. For future work the identification of individual tree canopies and canopy cover from high-resolution imagery or aerial photographs could be used in combination with the results from the inventory, to refine the carbon estimates presented here.

The local inventory described corresponds to a Tier 3 approach under recent IPCC guidelines. However, suggested practices for the full implementation of Tier 3 were not adopted. The following activities could be performed as part of future fieldwork to refine the estimates: verify the suitability of the allometric equations used; undertake external verification and advanced quality assurance and control practices during a second inventory campaign; use satellite images with higher resolution; include other carbon pools (i.e. soils and organic dead matter); and include advanced forest dynamics models. It is necessary to undertake periodic forest inventories to monitor further increments and carbon enhancements in the different carbon pools.

4.7. Conclusions

Results indicate that in degraded forests like La Primavera, long-term potential increments from forest enhancements might be comparable in size to the current carbon stocks. Results based on local field data stratified by canopy cover produce estimates which are comparable with the lower ends of the IPCC default values for carbon content in biomass and with national inventories in México. Results also indicate that it may not be unreasonable to use conservative IPCC default values to estimate carbon stocks in biomass. Estimates of biomass growth based on inventory data and equations modelling tree growth also provide results similar to default values, but it is necessary to validate these figures as part of future work; especially if modelling over the long term is required. While it is possible to get conservative estimates of carbon enhancements using mid-resolution satellite imagery such as Landsat in combination with *ad hoc* forest inventories, it is necessary to identify any systematic errors in the evaluation of canopy cover by comparing the results drawn from this set of remotely sensed data with high resolution images or photographs. However, results presented here can help to identify the scale and differences in carbon stocks and potential enhancements across areas with different level of degradation. In order to estimate the potential total carbon forest services that could be produced in the study area, the effect of the selection of the REL was analysed. The selection of the REL is a critical aspect defining the scale of total forest carbon services. Thus it is necessary to design the appropriate mix of incentives and controls to reduce emissions and enhance carbon without generating moral hazards and perverse incentives. Although carbon enhancements can be measured in areas currently under threat of degradation or deforestation, it is important not to forget that the risk imposed by the very factors driving carbon emissions are the major obstacles in realizing carbon potential in forests under REDD+.

5. Using basal area to estimate aboveground carbon stocks in forests: La Primavera Biosphere's Reserve, México[13]

5.1. Abstract

Increasing use of woody plants for greenhouse gas mitigation has led to demand for rapid, cost effective estimation of forest carbon stocks. Bole diameter is readily measured and basal area can be correlated to biomass and carbon through application of allometric equations. We explore different forms of allometric equation and analyze the potential to use equations for individual trees to derive stand level equations, where basal area and average diameter are used as explanatory variables. To test the relationships derived from published allometric equations we used data from a forest inventory in the oak-pine forests in La Primavera (México). Results show that in two forests with the same species and basal area, there will be more carbon where trees are larger. Allometric equations for individual trees can be transformed into stand-level equations. Values of average diameter weighted by basal area to be used in these equations can be based on a small sample of large trees once the local relationship between tree size and tree density per hectare is known. This approach could considerably reduce field data requirements in comparison with inventory methods based on enumeration of all trees for estimation of biomass and carbon.

5.2. Introduction

Basal area, the sum of cross sectional area measured at breast height (1.3m) of all trees in a stand, expressed as m^2/ha, has frequently been used as a surrogate for biomass and carbon in tropical moist and dry forests (Tadaki et al., 1961; Brown et al., 1989; Singh and Singh, 1991; Whittaker, 1966; Chiba, 1998; Phillips et al., 1998; Clark and Clark, 2000; Baker et al., 2004; Lewis et al., 2004; Murali et al., 2005; Sagar and Singh, 2006; Mani and Parthasrathy, 2007). Basal area is a good predictor for biomass and carbon since it integrates the effect of both the number and size of trees (Burrows et al., 2000). A correlation between these variables is to be expected since basal area and biomass are both related to trunk diameter (Sarmiento et al., 2005).

Previous studies have used basal area for different purposes, for example, to identify the ratio of biomass to basal area (Burrows, 1976; Scanlan, 1991; Brown, 1996; Burrows et al., 2000; Clark and Clark, 2000); to estimate biomass expansion factors (Brown et al., 1989); to predict biomass of trees (Haase and Haase, 1995); to predict biomass at stand level in combination with mean tree height (Cannell, 1984; Dagnelie et al., 1985; Masera et al., 1997) and to obtain estimates of biomass of fine roots (Finér et al., 2011). Basal area has been found to be the best predictor of

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biomass in open dry forests, giving better results than canopy cover or leaf area index (Suganuma et al., 2006).

As Burrows et al., (2000) point out, the relationship between biomass and basal area could be used to facilitate the estimation of biomass since basal area can be rapidly measured on the ground through different methods e.g. Bitterlich stick (Grosenbaugh, 1952), prism sweep method (Dilworth and Bell, 1971), relascopes or dendrometers (e.g. DECCW, 2010), which do not require individual tree measurements, thus speeding up the process considerably. Moreover, in some sites there is information available for basal area over large areas for long periods (Murali et al., 2005), which would allow historical estimates of biomass to be made; these are necessary, for example, in setting baselines for stock increases/decreases. The relationship between these variables could also be used in combination with remote sensing to scale up biomass and carbon figures over extensive tracts of forest (O'Grady et al., 2000), since high resolution images can be used to derive basal area and other stand-level variables once the model is calibrated for a given site (Lefsky et al., 1999; Yao et al., 2001; Broadbent et al., 2008; Gonzalez et. al. 2010; Naesset et al., 2011).

Mitigation of climate change through forestry-based strategies to reduce emissions from deforestation and forest degradation and to enhance carbon sequestration by forests, such as contained in the REDD+ policies (e.g. UNFCCC, 2010a; UNFCCC, 2011b), requires the measurement and monitoring of carbon stocks and stock changes in forests (UNFCCC, 2010a). However, if basal area is to be used in estimating biomass, it is essential that the nature of the relation between these two variables is well understood. Based on pipe model theory, Chiba (1998) suggested a linear relationship between basal area and biomass. Linear and near-linear relationships between these two variables have been reported and used in the literature for a wide range of forest types from tropical dry open forests in Australia and India to rainforests in the Amazon (e.g. Martínez-Yrizar et al., 1992; Phillips et al., 1998; Burrows et al., 2002; Baker et al., 2004; Murali et al., 2005; Araujo-Murakami et al., 2006; Suganuma et al., 2006; Mani and Parthasrathy, 2007). The relationships at plot-level correlating biomass and basal area have been called 'stand allometric equations' (Burrows et al., 2000). Stand-level equations for different species have been developed from equations for individual trees to estimate the volume of timber in a stand while minimizing the number of measurements and calculations required (Rondeux, 2010).

The objective of this work is to assess the potential use of basal area to predict aboveground biomass and carbon at the plot-level. For this, we discuss whether the relationship between basal area and carbon is expected to be linear or not and the implications of applying different models derived from allometric equations. Based on these results we explore the potential to modify allometric equations for individual trees into stand-level allometric equations where basal area is an independent variable. Field data from a standard forest inventory in which individual trees in sampling plots were measured in La Primavera Biosphere Reserve in México was used to explore the accuracy of this approach. We discuss the potential of transforming allometric equations for individual trees into stand allometric equations to estimate aboveground biomass and carbon; and the possibility of reducing effort in collection of fieldwork data for estimation of carbon stocks. First, the relationship between carbon and basal area in allometric equations with different specifications is discussed. This is followed by a description of the forest inventory data. Results, discussion and conclusions are then presented.

5.3. Basal Area and Carbon from Allometric equations

Allometry, as initially proposed by Huxley and Tessier (1936), studies how the characteristics of organisms change with size (Shingleton, 2010). In forestry, allometric equations usually describe the change in biomass stocks in a tree as a function of readily measurable characteristics, typically: bole diameter, tree height, species and wood density. The most important predictor of biomass in trees is bole diameter at breast height (D) (Chave et al., 2005). Allometric equations are used to estimate carbon and biomass from individual trees and inventory plots; and these are then scaled up to stand and landscape levels (Brown, 1997; Návar, 2010). The equations follow a variety of mathematical specifications (e.g. log linear, non linear) and are obtained for specific ranges of tree size (Návar, 2010). We analyze the relationship between carbon and basal area for three types of equations generating values for carbon (Equations 5.1 to 5.3). Allometric equations usually estimate the amount of dry biomass, this can be converted to carbon by multiplying the results by the percentage of carbon in dry biomass; we use a default factor of 0.50 (IPCC, 2003) to convert biomass to carbon figures in Equations 5.1 to 5.3. Equation 5.1 depicts the general form of the most common specification used, the log linear model (Zianis and Mencuccini 2004; Návar 2010). Equation 5.2 corresponds to the form used in default equations for hardwoods and conifers in IPCC Guidelines (IPCC, 2003); Equation 5.3 represents a quadratic polynomial regression form, such as those presented by Brown (1997) for large trees and tropical trees.

$$C = K * D^x \quad \text{(Equation 5.1)}$$

$$C = a + \frac{b * D^x}{D^x + c} \quad \text{(Equation 5.2)}$$

$$C = d + e * D + f * D^2 \quad \text{(Equation 5.3)}$$

In equations 5.1 to 5.3, C represents the amount of carbon in individual trees (tC $tree^{-1}$), D is the diameter at breast height in cm and K, x, a,b,…,f are constants obtained from the regressions made for the development of the allometric equations.

In order to obtain the expression for the relationship between carbon and basal area we first consider the model presented in Equation 5.1 (the log linear model). The expression for basal area (G) of an individual tree is the equation for a circle, presented in Equation 5.4 (expressed in m^2/tree). Since D is the value of the trunk diameter in cm, a factor of 40,000 is used to obtain the area in m^2, assuming the tree base has a circular form, in Equation 5.4.

$$G = \frac{\pi}{40{,}000} * D^2 \quad \text{(Equation 5.4)}$$

Equation 5.5 is proposed to analyze the relationship between carbon and basal area, in a similar manner to that used by Chiba (1998). Here *m* indicates the proportionality between these variables; if the relationship between these variables is linear then *m* will be a constant (Chiba, 1998); *m* is in units of carbon per square meter of basal area (tC/m^2).

$$C = m * G$$ (Equation 5.5)

By substituting equations 5.1 and 5.4 into equation 5.5 the expression for *m* can be obtained for this allometric specification (Equation 5.6).

$$m = \frac{C}{G} = \frac{40{,}000 * K * D^x}{\pi * D^2} = K' * D^{x-2}$$ (Equation 5.6)

Where K' is: $K' = \frac{40{,}000 * K}{\pi}$ (Equation 5.7)

It can be seen in equation 5.6 that *m* would be constant thus implying a linear relationship between basal area and carbon only when the exponent *x* in the log linear model is equal to 2; in this case the slope will be equal to K'. When *x* is of a value other than 2, the ratio between basal area and carbon will depend on tree size, being a function of D to the power of *x*-2. For $x<2$, *m* will decrease as the size of the trees increases. Conversely for $x>2$ there will be more carbon per unit of basal area for larger trees; this might be the most common case since the theoretical and empirical values of *x* are in fact 2.67 (West et al., 1999; Zianis and Mencuccini, 2004;) and 2.37 (Zianis and Mencuccini, 2004). In their review of 277 allometric studies, Zianis and Mencuccini show that the value of *x* was above 2 in 94% of the cases reviewed; only in rare cases did the allometric equation imply a strict linearity between basal area and carbon or a diminishing value for *m* with increased tree size.

The expression for above ground arboreal carbon as function of basal area for an individual tree can be obtained by solving for C in equation 6 (Equation 5.8):

$$C = K' * D^{x-2} * G$$ (Equation 5.8)

The process described above can also be developed for the non-linear models represented in equations 5.2 and 5.3. This will give us equations expressing carbon as function of basal area in equations 5.9 and 5.10, which are equivalent to equation 5.8.

$$C = m * G = \left(\frac{a * k}{D^2} + \frac{b * k * D^x}{D^{2+x} + c * D^2} \right) * G$$ (Equation 5.9)

$$C = m * G = k * \left(\frac{d}{D^2} + \frac{e}{D} + f \right) * G$$ (Equation 5.10).

Where k=40,000/π.

Equations 5.9 and 5.10 represent more complex non-linear relationships between basal area and carbon. The mathematical expression in equation 5.9 implies that for large trees as D increases, the value of *m* decreases, in fact for very large D values, which might be outside the valid range for the equation, the expression implies that the value of *m* tends to zero. It is important to recall that allometric equations are prepared for a specific range of D values hence equations should be used only within these ranges of validity. On the other hand the expression for *m* in Equation 5.10 implies that when D increases it will reach an asymptotic value equal to 40,000**f*/π where *f* is the coefficient of the quadratic term in Equation 5.3. Equations 8 to 10 show that none of the three allometric models considered supports the assertion that the relationship between basal area and carbon is strictly linear when the data from individual trees is considered for a wide range of D.

Equation 5.8 can be converted into a stand allometric equation if values of basal area per hectare and the average diameter ($\overline{D}$) are available (equation 5.11); in this case $\overline{C}$ represents the carbon (tC/ha) and $\overline{G}$ is basal area (m^2/ha) obtained at the inventory plot level.

$$\overline{C} = K'^{*}\overline{D}^{\,x-2} * \overline{G} \quad \text{(Equation 5.11)}$$

Most studies relating biomass and basal area have followed an approach based on the use of allometric equations for individual trees. Typically a forest inventory is carried out and biomass/carbon figures for individual trees are obtained using local or published allometric equations to derive aggregated values per site or per hectare; then the relationship between basal area and biomass/carbon is analyzed with the aggregated information per hectare. An alternative approach is that followed by Martínez-Yrizar et al., (1992), in which they directly compared biomass figures in a dry tropical forest to the basal area of the plots where trees were cut. However, this latter approach depends on destructive sampling and would require that instead of cutting down, measuring and weighing individual trees, entire sites (with different values of $\overline{D}$ and basal area) would need to be cut down, thus increasing the cost of developing these allometric relationships.

There is one issue to be addressed in equation 5.11, while figures for basal area can be obtained in the field without taking physical measurements from each tree (e.g. by using a relascope), it is necessary to find a method to obtain the average diameter without having to measure all the trees in a site (otherwise the sampling effort would be no less than that for the establishment of inventory plots and complete enumeration of trees). In the simplest case that can be depicted, all the trees in a site could have the same diameter. In this special case equation 5.8 can be rearranged to give the obvious result that carbon is simply the product of the carbon per tree multiplied by the density n (trees/ha), and D in equation 5.8 will be equal to the average $\overline{D}$ in the inventory plot in equation 5.9 (Appendix A).

However, in reality not all the trees in a forest and in a plot will have the same D. The simple mean $\overline{D}$ in the site could be used in equation 5.11, however, by reference to equation 5.8 we can argue that since trees with larger diameters might contribute more to the carbon stock per unit of basal area, then also the diameter of the larger trees should contribute more to the average diameter to be used in equation 5.9. One option to account for this effect would be to use the diameter weighted by basal area ($\overline{D_G}$) instead of the simple average; however, for this, all trees in a site would have to be measured individually to obtain the weighted average. The objective of our analysis is to reduce the measurement effort and generate consistent values for the diameter to be used in the stand allometric equation. For this, we select only a portion of the trees in an inventory site to obtain a weighted average for the sub-sample ($\overline{D_{G'}}$). If we consider a sub-sample of size one, including only the largest tree in the plot ($D_{max}=\overline{D_{G'}}$) we know that $\overline{D_{G'}} > \overline{D_G}$ and thus $\overline{D_{G'}} / \overline{D_G} > 1$. For every tree we include in this sub-sample, by order of descending D, the value of $\overline{D_{G'}}$ will decrease. Naturally, as the number of trees in the sub-sample gets closer to that of the trees in the site, $\overline{D_{G'}}$ will converge to $\overline{D_G}$ thus $\overline{D_{G'}} / \overline{D_G}$ will decrease and reach the value of one only when all, including the last (smallest) tree, is included in the sub-sample. It is important to note however, that the weight of each additional tree that is included in the sub-sample will be diminishing since its relative contribution to the basal area will be steadily smaller in comparison to the accumulated basal area of the largest trees already included.

In order to derive the value of $\overline{D_G}$ as function of $\overline{D_{G'}}$ of a sub-sample of large trees we use the inverse relationship between tree size and tree density. Reineke (1933) showed a negative relationship between the logarithms of the mean quadratic diameter and stand density consistent for different tree species in natural forests and plantations (Shaw, 2006). At higher tree densities the area available for each tree to grow is reduced (Kuuluvainen, 1991; Foli et al., 2003). Thus the growing space, and potential growth of the trees, would be inversely related to tree density (Kuuluvainen, 1991). Considering this, equation 5.12 is proposed to relate tree density to $\overline{D_G}$.

$$\overline{D} = \frac{A}{n^z} \quad \text{Equation 5.12}$$

In equation 5.12, *A* and *z* are constants and n is the tree density per hectare. If for a sub-sample taken, the value of $\overline{D_{G'}}$ is also found to be inversely correlated with tree density, then Equation 5.13 could be used.

$$\overline{D_{G'}} = \frac{A'}{n^{z'}} \quad \text{Equation 5.13}$$

By dividing equation 5.13 by equation 5.12 the equality holds (Equation 5.14), and from this the expression to find $\overline{D_G}$ as function of $\overline{D_{G'}}$ of a sub-sample and tree density can be found (Equation 5.15).

$$\frac{\overline{D_{G'}}}{\overline{D_G}} = \frac{A'*n^{z}}{A*n^{z'}} \text{ Equation 5.14}$$

$$\overline{D_G} = \frac{A*n^{z'}}{A'*n^{z}} * \overline{D_{G'}} = \frac{A}{A'} n^{z'-z} * \overline{D_{G'}} \text{ Equation 5.15}$$

Equation 5.15 can be obtained for a specific forest type or region and so can be used to correct the diameter figures obtained on the ground measuring a sub-sample of large trees estimated ($\overline{D_{G*}}$) (Equation 5.16); this corrected value can be used in the stand allometric equation.

$$\overline{D_{G*}} = \frac{A}{A'} n^{z'-z} * \overline{D_{G'}} \text{ Equation 5.16}$$

Based on this analysis we use the data from a forest inventory to calculate $\overline{D}$ and $\overline{D_G}$ and use them in stand allometric equations together with the plot level values of basal area to estimate carbon figures and compare the results with those based on the enumeration of trees. In order to assess the potential to reduce sampling effort to obtain an appropriate value of diameter, we estimate $\overline{D_{G'}}$ in each inventory plot for different sub-samples of large trees. For this we first ordered the data of all the trees in each plot from largest to smallest D. Then for each plot we took eight sub-samples considering the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th and 10th largest trees. We calculated the ratio $\overline{D_{G'}} / \overline{D_G}$ for each site and sub-sample and plotted it against tree density; we obtain a power regression between the ratio and tree density consistent with Equation 5.14 from which functions following equation 5.16 are derived. These equations are used to estimate a value of $\overline{D_{G*}}$ in each site based on $\overline{D_{G'}}$ from each sub-sample of large trees. This estimated $\overline{D_{G*}}$ is used to obtain carbon using the stand allometric equations; the results generated following this approach are compared with those obtained through the enumeration of trees (i.e. carbon content is estimated using the stand allometric equations and the D from as few as one tree in each plot, which is corrected by equation 5.16).

5.3.1. Allometric equations

The equations used to assess the use of basal area for the estimation of biomass and carbon are presented in Table 5.1 and include: the equations developed by Návar (2009) for oaks and pines in northwestern México, these consider the content in the trunk, branches and leaves; the equations published by Brown (1997) for broadleaved trees and conifers, as used by de Jong et al., (2010) for the national inventory of carbon emissions from deforestation in México; the Equation suggested for largest trees and tropical regions suggested by Brown (1997); and the default equations for conifers and hardwoods published by IPCC (2003). These equations exemplify the three specification forms discussed above (Equations 5.1, 5.2 and 5.3). The associated stand allometric equations to estimate carbon figures directly from stand level data are included in the last column of the table.

Table 5.1 Allometric equations used in the analysis of the carbon/basal area relationship.

	Equation for Individual Trees.		**Stand Allometric equations (Carbon in t/ha)[a]**
	Allometric equation (Carbon in kg/tree)	**D range, species (Source)**	
1	$0.50*0.0752*D^{2.4448}*2.0331^{\rho}$	7.3-62.5 cm, Oaks, 5.7-57.4cm Pines, (Návar, 2009[b])	$\frac{0.50}{1000}*k*0.0752*2.0331^{\rho}*\overline{D}^{0.4448}*\overline{G}$
2	$0.50*\exp(-1.966)*D^{2.32}$	5 -40 cm, Broadleaves (Brown, 1997[c])	$\frac{0.50}{1000}*k*\exp(-1.966)*\overline{D}^{0.32}*\overline{G}$
3	$0.50*\exp(-1.170)*D^{2.119}$	2-52 cm, Conifers (Brown, 1997)	$\frac{0.50}{1000}*k*\exp(-1.170)*\overline{D}^{0.119}*\overline{G}$
4	$0.50*(42.69-12.800*D+1.242*D^2)$	5 – 148 cm, Broadleaves (Large Trees)(Brown, 1997[d])	$\frac{0.50}{1000}*k*\left(\frac{42.69}{\overline{D}^2}-\frac{12.800}{\overline{D}}+1.242\right)*\overline{G}$
5	$0.50*(21.297-6.953*D+0.740*D^2)$	4- 112 cm (Tropical trees. (Brown, 1997[e])	$\frac{0.50}{1000}*k*\left(\frac{21.297}{\overline{D}^2}-\frac{6.953}{\overline{D}}+0.740\right)*\overline{G}$
6	$0.5*(0.50+\frac{25000*D^{2.5}}{D^{2.5}+246872})$	1.3 – 82.2 cm, Temperate US Eastern Hardwoods (IPCC, 2003)	$\frac{0.50}{1000}*k*\left(\frac{0.50}{\overline{D}^2}+\frac{25000*D^{2.5}}{\overline{D}^{4.5}+246872*\overline{D}^2}\right)*\overline{G}$
7	$0.5*(0.887+\frac{10486*D^{2.84}}{D^{2.84}+376907})$	0.5-56 cm, Temperate/Tropical Pines (IPCC, 2003)	$\frac{0.50}{1000}*k*\left(\frac{0.887}{\overline{D}^2}+\frac{10486*D^{2.84}}{D^{4.84}+376907*\overline{D}^2}\right)*\overline{G}$

[a] $\overline{D}$ is the average D in the plot in cm, G is the basal area in m^2/ha and k is $40{,}000/\pi$; quantities are divided by 1000 to convert from kg to ton.
[b.]Wood specific density ρ, Oak=0.63;Pine=0.55, Návar, 2009.
[c.]Broadleaves, Precipitation range 800 to 1500 mm
[d]Moist Climatic Zone (Brown, 1997)
[e]Wet climatic zone.

Figure 5.1 Relationship between the basal area to carbon ratio (*m*) as a function of diameter at breast height (D) for the allometric equations shown in Table 5.1

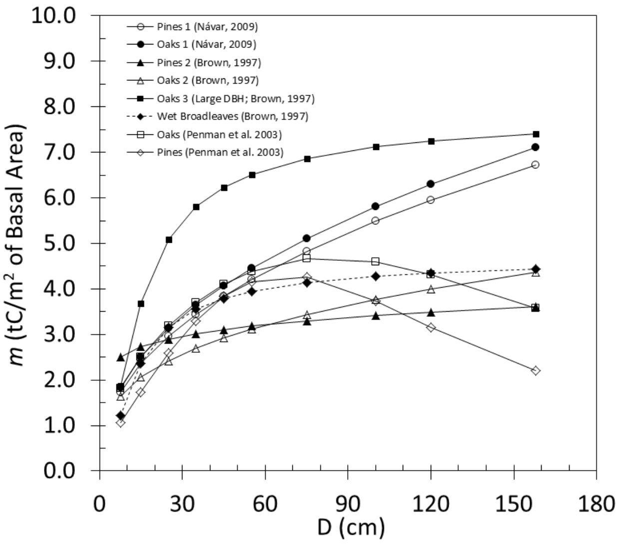


Figure 5.1 shows the value of *m* as function of D for the selected equations. If the relationship between basal area and carbon were strictly linear, the graphs for *m* in Figure 5.1 would be horizontal lines. However, Figure 5.1 shows that for all the equations considered *m* is smaller for trees of small diameters and that there is a first phase in which it increases rapidly with tree size; in some cases the ratio thereafter tends to an asymptotic value resembling a horizontal line. As expected given the equations reported by IPCC, 2003 (following the specifications of Equation 5.2), after D reaches about 60cm *m* starts to decrease; however, these equations were prepared for D ranges below 82.2 for hardwoods and 56 cm for pines and thus they should not be used for trees of larger size. Brown (1997) suggests equation 4 in Table 5.1 for the largest trees, showing an increasing content of carbon per unit of basal area. The equations of Návar (2009) include the effect of wood specific gravity and produce similar values to those obtained through the IPCC's default equations (IPCC, 2003) for small D values. Návar´s equations also produce similar values to those derived from the equation suggested by Brown (1997) for large trees. Thus the equations of Návar (2009) may provide a good fit for oaks and pines for a wide range of D values. The equations of Návar do not present an asymptotic trend.

For purposes of comparison we included in Figure 5.1 the equation for the wet climatic zone corresponding to rainforests (Brown, 1997). It can be seen that for diameters above 30 to 40 cm the value of *m*, while it still is increasing, does so at a very low rate, thus it may resemble a horizontal line in Figure 5.1. This may explain why a linear relationship between carbon and basal area has been used for rainforests (e.g. Phillips et al., 1998; Baker et al., 2004), since in the permanent measurement plots used in intact tracts of forests in the cited studies, D values may be large, the values would be relatively homogenous and would not include stands with small average D values. However, this apparent linearity might not apply to stands and forests with smaller trees. The linear relationship between carbon and basal area obtained from stands with trees of large D will overestimate carbon figures if used to estimate carbon during the first years in plantations, in reforested areas or in areas with trees with smaller D.

5.4. Forest Inventory

Data from a forest inventory carried out in La Primavera Biosphere Reserve in Jalisco, México, were used to compute carbon estimates using two sets of allometric equations and following the standard IPCC methodologies (IPCC, 2003). Here we explore the potential and pitfalls of using basal area as a predictor for carbon in the inventory data. The allometric equations used were those developed by Návar (2009) and those published by Brown (1997) (Equations 1 to 3 in Table 5.1). The inconvenience of performing destructive sampling to obtain local allometric equations needs to be carefully evaluated, it may be only justified if the forest will continue to be monitored with a large number of measurement plots (more than 40), otherwise uncertainty associated with a small number of plots will be higher than that of the allometric model (Van Breugel et al., 2011); moreover, a large number of trees would need to be cut down since regional or pantropical equations should generate results of higher quality than those from equations based on small samples (less than 100 trees) and with a small range of D values (Chave et al., 2004). Thus we used published allometric equations as a first approximation, if future activities such as sub-national REDD+ projects in the region are to be undertaken it is recommended to sample a few trees and evaluate if published equations are suitable; and if not develop local equations.

La Primavera forest is a Biosphere Reserve encompassing 30,500 ha located in the State of Jalisco in México (CONANP, 2000; UNESCO, 2011). It consists mainly of oak pine mixes but tropical deciduous forests, natural grasslands, and agricultural areas are also present. The altitude ranges from 1400 to 2200 masl. Annual mean temperature is 20.6ºC and annual precipitation ranges from 800-1000 mm, which defines it as a montane tropical forest (CONANP, 2000; IPCC, 2003). Regosols and lithosols are the principal types of soils present; in general soil is poor and affected by erosion and recurrent fires.

The inventory focused on the measurement of trees in oak-pine mixed forests; 103 measurement plots of 30 x 30 m were established between June-July 2009. Variables measured included D, total height, height to the base of living crown, and crown diameter. All trees with D larger than 7.5 cm were measured, sprouts bifurcating below 1.3 m height were considered to be individual trees. The length of the plot sides was corrected for slope. Basal area was obtained by summing cross sectional area at breast height for all trees in the measurement plots. The aim of the forest inventory was to create 95% confidence intervals for the expected aboveground carbon content per hectare (in trees) with a margin of error of less than 10%. Pre-stratification was initially made by canopy cover classes based on aerial photographs for the location of the measurement plots including the different conditions present in the forest (Low <30% 15 sites, Medium 30-60% 48 sites and High Canopy Cover > 60% 40 sites). Sites were located randomly over areas with slopes of less than 65%; the average slope of the sites sampled was 12% (range 1% to 60%). The mean altitude was 1713 masl (range 1410-2180).

The equations of Návar (2009) are considered to be the best available published equations to derive aboveground carbon estimates in La Primavera as they were obtained in oak-pine forests in northwestern México with similar soil types and precipitation ranges to those in La Primavera; they produce similar values as those of the default equations by IPCC and those for larger trees. de Jong et al., (2010) used the equations of Brown (1997) to estimate emissions from deforestation as part of the third national communication to the UNFCCC because they provided the lowest figures for biomass (de Jong et al., 2010 page 1699); here we include the equations of Brown (1997), since we did not perform local truthing of the allometric equations, in order to be consistent with the national inventory and to evaluate the effect of using different allometric equations when using basal area as predictor of carbon.

5.5. Results

5.5.1. Forest Inventory

In the forest inventory 3,412 living trees of 14 different species were measured (nine species of Oaks, n=2291; two of Pines, n=1102; and three from other genera n=16); the dominating species were *Quercus resinosa* Liebm. and *Pinus oocarpa* Schiede ex Schltdl. The largest D registered corresponded to a *Quercus castanea* Née (158cm) whose crown (36m) covered more than the area of one plot. Table 5.2 presents the general results of the inventory at plot level.

The ranges for D, density, canopy cover and basal area indicate the heterogeneity of the sites measured.

Table 5.2 General characteristics of the forest inventory at measurement plot level.

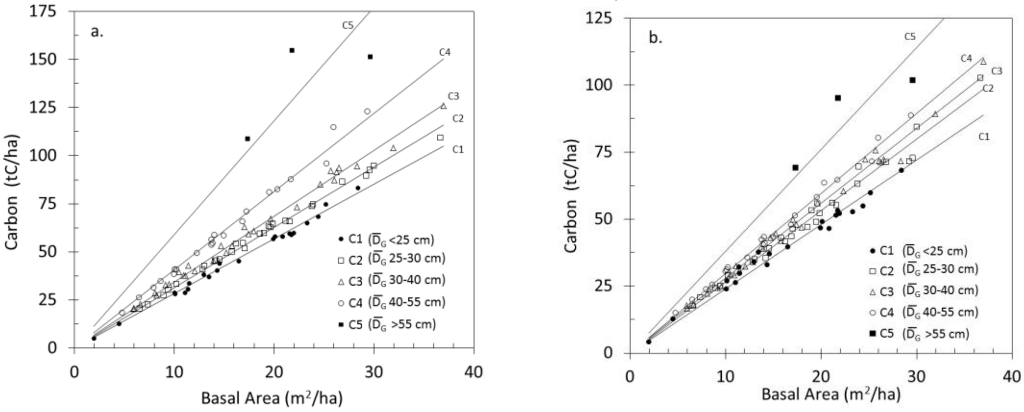
Variable	Mean	S.D.	Range
Basal area (m^2/ha)	17.0*	7.5	1.9- 37.0
Canopy cover (%)[a]	54%*	22%	10- 96%
Density (trees/ha)	368	280	11- 1,144
Mean D in site (cm)	27.3	15.8	14.7- 158.0
Mean crown diameter in site (m)	6.3	4.4	1.9- 36.3
Mean height in site (m)	12.2*	4.3	3.6 - 35.9
% of Oaks	62%*	30%	0- 100%
Carbon (tC/ha) (Návar, 2009)	58.5*	28.8	5.3- 155.0
Carbon (tC/ha) (Brown, 1997)	46.9*	21.5	4.2- 109.0

*The sample size is sufficient to generate 95% C.I. with an error of 10% for this variable.
[a]Canopy cover maps were drawn in 90 sites.

The inventory data allowed generation of 95% confidence intervals for basal area, carbon and other variables of interest within this forest. The equations used in the national inventory generate conservative estimates as indicated by de Jong et al., (2010) and are 21.4% lower in comparison with the results from the equations of Návar (2009).

5.5.2. Carbon and Basal Area

Figure 5.2 Relationship between carbon and basal area for the two sets of equations, trees in the plots are classified by different size class according to the weighted diameter (D_G).Figure 5.2a, carbon estimates using the equations published by Návar, (2009); Figure 5.2b, carbon estimates using the equations published by Brown (1997).



Basal area and carbon estimates obtained through the complete enumeration of trees were plotted for the two sets of equations to test the fit with linear regressions (Figures 5.2.a and 5.2.b). Table 5.3 presents the information of the equations relating carbon to basal area shown in Figures 5.2.a and 5.2.b. When the data from the 103 sites is regressed together as one sample the relationship between carbon and basal area fits well to a straight line passing through the origin (Table 5.3, ‘All Sites’). However, when the sites of the inventory were classified by the weighted diameter ($\overline{D_G}$) the adjusted R^2 and the standard error of the estimates improved considerably (Table 5.3). For the two sets of equations, the slopes of the straight lines increase as tree size increases and are statistically different (Table 5.3) This increase in the slope with tree size was expected based on the analytical discussion presented in the previous section and implies that at constant basal area values, there is more carbon in those areas with larger trees. Only the slope of the Equation for the last diameter class, which includes the largest trees, is not statistically different, however, the subsample for this size range was very small. The dispersion of the data in Figure 5.2a and 2b resembles that presented by Chiba (1998), Bi et al., (2010) and Burrows et al., (2000), showing a heteroskedastic pattern for larger values of basal area. This dispersion of the data for larger values of basal area is explained by the variation in tree size. The carbon to basal area ratio (value of *m*) for all the inventory plots was estimated and plotted against the corresponding weighed diameter area $\overline{D_G}$ in each sites (Figure 5.3)

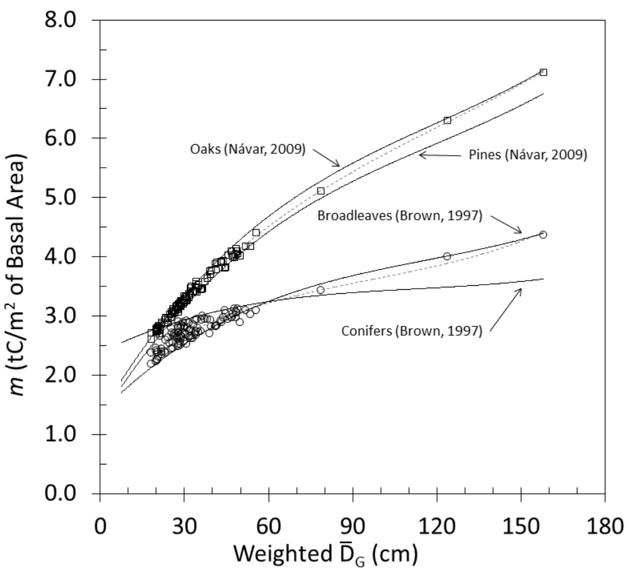
Table 5.3 Statistical information for the linear regressions between carbon and basal area stratified by D_G presented in Figures 3a and 3b.

Model (Classes by $\overline{D_G}$)	n	Set 1 (Návar, 2009)				Set 2 (Brown, 1997)			
		m (tC/m^2-G)	95% C.I. for *m*	S.E.	R^2	*m* (tC/m^2-G)	95% C.I. for *m*	S.E.	R^2
AllSites	103	3.438	3.299 - 3.576	13.126	95.9%	2.755	2.690 - 2.820	6.211	98.5%
C1 ($\overline{D_G}$ <25 cm)	22	2.839	2.796 - 2.882	1.703	99.9%	2.401	2.341 - 2.462	2.422	99.7%
C2 ($\overline{D_G}$ 25 - 30 cm)	28	3.130	3.096 - 3.165	1.778	99.9%	2.664	2.609 - 2.720	2.852	99.7%
C3 ($\overline{D_G}$ 30-40 cm)	29	3.424	3.376 - 3.472	2.356	99.9%	2.794	2.744 - 2.843	2.462	99.8%
C4 ($\overline{D_G}$ 40-55 cm)	21	4.065	3.982 - 4.148	2.992	99.8%	2.983	2.937 - 3.029	1.655	99.9%
C5 ($\overline{D_G}$ >55 cm)	3	5.906*	3.218 - 8.594	25.380	96.7%	3.806	2.548 - 5.065	11.881	98.3%

$\overline{D_G}$: D average weighted by contribution to basal area in each inventory plot.

*Significance of the regression 0.011, significance of the slope *m* 0.011; for all the other regressions the significance of the regression and the slope are higher than 0.001.

Figure 5.3 Comparison of the carbon to basal area ratios from the inventory measurement plots and allometric equations. The two sets of curves for pines and oaks are presented for the estimates obtained using the equations published by Návar, (2009) and those using the equations published by Brown (1997).



In Figure 5.3 the solid curves correspond to the value of *m* for pure oak or pine stands from the allometric equations. Most of the inventory sites were oak-pine mixes and as expected they lie between the two lines corresponding to the pure oak or pine stands (Figure 5.3). The data of the measurement plots corresponds to the value of *m* obtained from the forest inventory; carbon in each tree in each plot was estimated using the corresponding equation for pines or oaks, then the total carbon and basal area per plot was computed; *m* in each plot was obtained by dividing the carbon content by the basal area value. The Figure 5.3 shows that when the data of *m* is plotted against the weighted diameter ($\overline{D_G}$) the values from the inventory plots fit well in comparison with curves from the allometric equations. It can be noted that in the equations of Návar (2009), for all diameters the value of *m* is higher for oaks than for pines; this is derived from a higher specific density of the wood. However, for the equations of Brown (1997) for trees below 60 cm, conifers will have higher values of biomass per unit of basal area, after this value *m* for broadleaves will be higher; this change should be reviewed in more detail in further allometric research. The stand allometric equations presented in Table 5.1 were used to predict the value of carbon per hectare following four different approaches (Table 5.4): (1) using the stand allometric equations, basal area and weighted average ($\overline{D_G}$); (2) using the stand allometric equation, basal area and simple average $\overline{D}$; (3) by obtaining the carbon content for a tree of size equal to the simple $\overline{D}$ average and multiplying it by tree density in the plot; (4) the same as previously, but using $\overline{D_G}$ instead. When the plot was oak dominated (> 70% of living trees were oak), the value of the equations for oaks was used; the same approach was followed for pine -dominated plots (> 70% of living trees were pines). For mixed stands the 50% of the values for oaks and pines were summed. Basal area figures were obtained from the aggregation of the basal areas of all the trees in the plots.

Table 5.4 Carbon estimates obtained using plot level data. Carbon figures present the mean, the standard deviation (S.D.) and the 95% range; the error is estimated for the four methods to estimate carbon using plot level data in comparison with the result from the inventory, the 95% range for the error is also presented.

Allometric equation/ Method based on Plot Level Data		Carbon tC/ha			Error (%)[b]	
		Mean	S.D.	95% Ranges[a]	Mean	95% Range[a]
Návar (2009)	Complete Enumeration of Trees	58.5	28.8	(19.4, 124.2)	-	-
	1) Stand Allometric equation ($\overline{G}$, $\overline{D_G}$)	59.3	29.2	(19.6, 127.2)	1.4%	(-4.0%, 6.0%)
	2) Stand Allometric equation ($\overline{G}$, $\overline{D}$)	53.1	26.0	(16.5, 112.1)	-8.7%	(-22.9%, 1.3%)
	3) Tree Density * Carbon in Tree of $\overline{D}$	46.9	23.4	(11.5, 102.1)	-19.0%	(-45.5%, -1.8%)
	4) Tree Density * Carbon in Tree of $\overline{D_G}$	67.5	46.8	(11.5, 182.4)	13.9%	(-42.4%, 131%)
Brown (1997)	Complete Enumeration of Trees	46.9	21.5	(15.9, 98.2)	-	-
	1) Stand Allometric equation ($\overline{G}$, $\overline{D_G}$)	47.3	21.8	(15.5, 96.5)	0.8%	(-11.4%, 17.8%)
	2) Stand Allometric equation ($\overline{G}$, $\overline{D}$)	44.6	20.5	(14.8, 93.4)	-4.8%	(-17.8%, 13.5%)
	3) Tree Density * Carbon in Tree of $\overline{D}$	39.3	18.2	(11.7, 81.0)	-15.8%	(-41.7%, 3.7%)
	4) Tree Density * Carbon in Tree of $\overline{D_G}$	69.9	37.9	(19.5, 162.9)	47.3%	(-0.4%, 135%)

[a]95% Range given by the 2.5% and 97.5% percentiles.
[b]$Error_i$ = ($Inventory_i$-Stand $AllometricEq._i$)/Inventory.
$\overline{D_G}$:D average weighted by contribution to basal area in each inventory plot.
$\overline{D}$: Simple D average in each inventory plot.

Table 5.4 shows that the best results are obtained when basal area and weighted diameter $\overline{D_G}$ are used with the stand level equation since this approach produces the closest estimates to those based on enumeration of individual trees (within 0.8% and 1.4% depending on the allometric model selected). The results obtained using this approach are very similar to those based on the complete enumeration of trees; variations appear due to differences in the composition of the plots (relative percentage composition of oaks or pines) and the simple rules to assign the value for pure or mixed plots as described above. Results also show that when the simple average $\overline{D}$ is used, then the carbon estimates are underestimated. Results from Table 5.4 and Figure 5.3 indicate that the use of average diameter weighted by basal area in the stand allometric equation generates accurate results in comparison with the enumeration of trees. Figures 4a and 4b show the values obtained through the enumeration of trees (horizontal axis), and those obtained using the stand allometric equation (vertical axis) for the equations of Návar and Brown. Results fit well to a straight line and the slope is very close to one, the standard errors of the estimates of a linear regression were 1.59 and 3.58 tC/ha respectively (Figure 5.4a and 5.4b).

In order to assess the potential to estimate an unbiased value of $\overline{D_G}$ and reduce the measurement effort, the relationship between the ratio $\overline{D_{G'}} / \overline{D_G}$ and tree density is obtained for three different sub-samples of large trees (Figure 5.5). The data of the inventory was used to generate the equations similar to those presented in equation 5.14, which are shown in Figure 5.5.

Figure 5.4 Comparison of carbon estimates obtained from complete enumeration and plot level data (a, Návar, 2009; b Brown 1997).

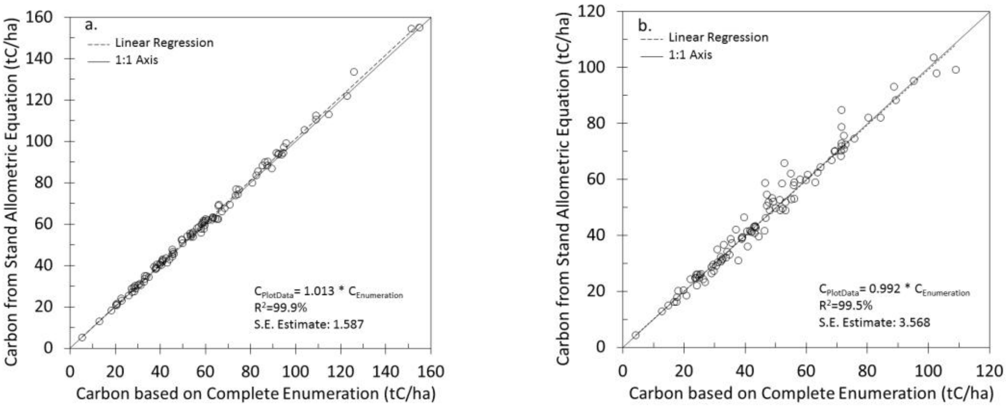
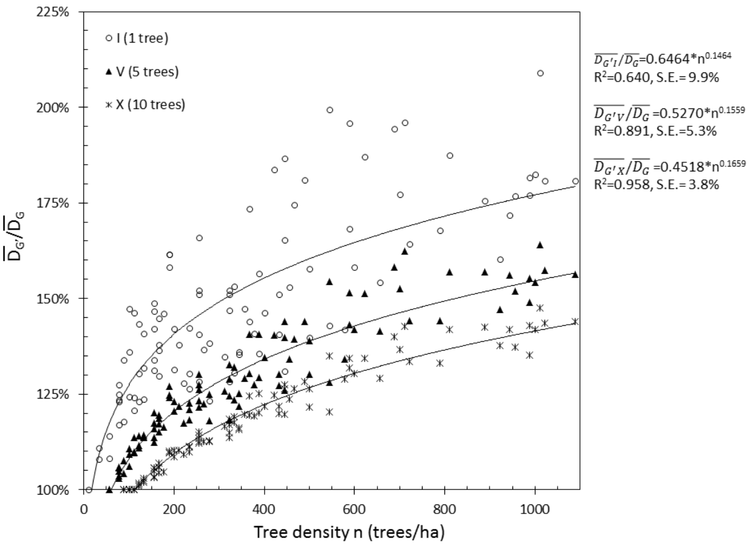
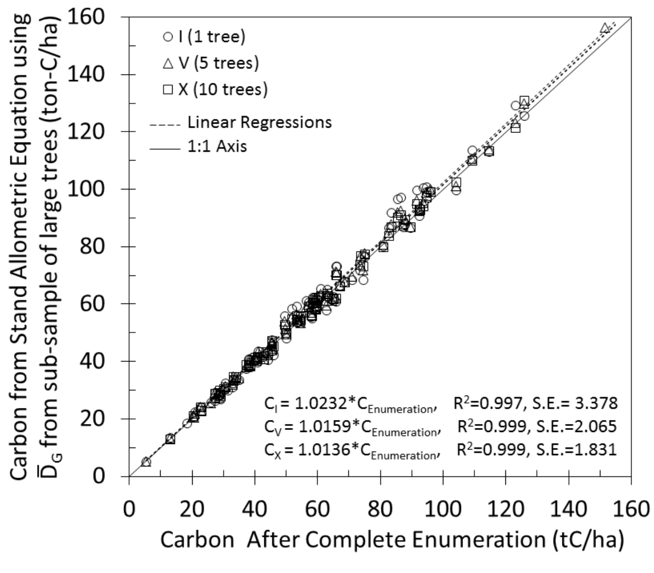


Figure 5.5 Plot of the ratio $D_{G'}/D_G$ against tree density in each measurement plot for three different sub-samples sizes of large trees (1st, 5th and 10th largest trees); power regressions following equation 5.14 are presented.



In Figure 5.5 it can be seen that when the sub-sample of large trees is larger, the standard error of the estimate will be smaller and the the R^2_{adj} will be higher. As expected the additional inclusion of trees in the sub-sample reduces the overestimation of the weighted diameter; this can be seen in the fact that the power relationships for each sub-sample are displaced downwards closer to the 100% line.

Figure 5.6 Comparison of carbon estimates obtained through the enumeration of trees in each inventory site (horizontal-axis) and those obtained using the stand allometric equation where diameter is estimated based on the sub-sample of the 1st, 5th and 10 th largest trees in each plot site and corrected by local tree density (vertical-axis); in both cases the equations of Návar (2009) were used.



The power regressions obtained following this approach are used to calculate $\overline{D_G}$ based on the value of $\overline{D_{G'}}$ for each sub-sample in each plot and the local density values from the inventory plot; this value is used jointly with the basal area to calculate carbon through the stand allometric equations. Figure 5.6 shows the fit between the data for carbon per hectare based on the enumeration of trees from the inventory data (horizontal-axis) and that obtained using the corrected $\overline{D_{G'}}$ and basal area using the stand allometric equations of Návar (2009) for a subsample of one, five and ten largest trees (vertical-axis). In Figure 5.6 it can be seen that even when only the largest tree in each plot is considered for the estimation of $\overline{D_{G'}}$ this procedure provides values similar to those obtained through the full enumeration of trees. The slope of the straight lines in Figure 5.6 indicates that on average the values will be between 1% and 2% higher depending on the sub-sample size; the standard error of the estimate in comparison with the inventory decreases as the size of the sub-sample increases; measuring the five largest trees reduces the standard error by about 40% in comparison with the measurement of the largest tree only. Table 5.5 shows the variation in the errors of these values in comparison with the results based on the full enumeration of trees using the equations of Návar (2009); results are presented for the pooled sites and stratified by tree density.

Table 5.5. Differences in carbon estimates obtained through the largest trees method and the stand level allometric equation, in comparison with carbon estimate based on the full enumeration of trees per plot (Mean values, in parenthesis the 95% range considering the percentiles 2.5% and 97.5%).

Sub-Sample (Size)	All Inventory Plots	Inventory Plots Classified by Tree Density			
		<10 trees/site (<111 trees/ha)	10-20 trees/site (111-222 trees/ha)	20-40 trees/site (222-444 trees/ha)	>40 trees/site (444-1100 trees/ha)
1	1.5% (-7.9%, 12.5%)	1.2% (-4.8%, 9.0%)	2.5% (-4.9%, 12.3%)	-0.2% (-8.1%, 8.4%)	2.8% (-4.5%, 12.7%)
2	1.4% (-6.5%, 9.9%)	0.8% (-4.1%, 7.0%)	2.4% (-5.0%, 10.0%)	0.2% (-6.7%, 8.6%)	2.5% (-4.0%, 10.2%)
3	1.4% (-5.2%, 8.9%)	0.8% (-3.5%, 6.7%)	2.2% (-5.2%, 8.9%)	0.5% (-5.5%, 8.0%)	2.3% (-3.8%, 9.4%)
4	1.4% (-4.8%, 8.3%)	0.8% (-3.3%, 6.5%)	1.9% (-5.1%, 8.1%)	0.7% (-5.1%, 7.4%)	2.2% (-3.8%, 8.6%)
5	1.4% (-4.7%, 7.7%)	0.9% (-3.1%, 6.4%)	1.8% (-5.1%, 7.5%)	0.9% (-4.8%, 7.0%)	2.1% (-3.8%, 8.0%)
6	1.4% (-4.6%, 7.2%)	0.9% (-3.0%, 6.2%)	1.7% (-5.1%, 6.9%)	1.0% (-4.4%, 6.7%)	2.0% (-3.8%, 7.4%)
7	1.4% (-4.7%, 6.8%)		1.6% (-5.2%, 6.6%)	1.1% (-3.9%, 6.4%)	1.9% (-4.0%, 7.1%)
10	1.6% (-4.7%, 6.5%)		1.7% (-5.0%, 5.9%)	1.3% (-3.1%, 6.0%)	1.8% (-4.3%, 6.4%)

Table 5.5 shows that on average this method generates results that are from 0.8% to 2.8% higher than those based on the enumeration of all trees, depending on tree density and the size of the sub-samples. The width of the 95% ranges for the errors decreases as the sub-sample of large trees increases, for the whole inventory (Column 'All Inventory Plots'), it goes from approximately ±10% when only the largest tree is measured; to ±6.2% when the sub-sample includes 5 trees, and ±5.5% for 10 trees. The columns showing the values for different tree density values can help to determine how many large trees should be measured to reduce sampling effort and keep the error low: e.g. for areas with less than 200 trees/ha measuring 3 trees per site would produce estimates within ± 5% to 7% of error while reducing the measurement effort by 70% to 85%; for areas with higher densities (>450 trees/ha) measuring the largest 5 trees generates estimates with error margins around ±6% error, but effort would be reduced by 87% to 95%.

The method to obtain $\overline{D_{G'}}$ adds the tree density as a new variable to obtain the carbon estimates (*i.e.* to correct $\overline{D_{G'}}$ and obtain $\overline{D_G}$ using the equations shown in Figure 5.5). However, the sensitivity of the results to errors in tree density is low (Appendix B). Appendix C presents the comparison of results based on $\overline{D_{G*}}$. $\overline{D_{G'}}$ against those based on $\overline{D_G}$ (from the forest inventory) using the stand allometric equation; in this way it is possible to isolate the effect introduced by using the method based on the sub-sample of large trees to determine $\overline{D_G}$. The mean differences in the carbon estimates are close to zero indicating that the results based on this alternative method targeting large trees are unbiased; the 95% range of the errors go below ±5% symmetrically distributed around the mean for sub-samples of two or more large trees.

5.6. Discussion

The results show that the relationship between basal area and carbon in most cases is not linear, as in the vast majority of published allometric equations the exponent *x* in the log-linear model is larger than 2, and that allometric equations for individual trees can be modified to produce stand level equations in which basal area is an additional independent variable; these equations are similar to those used in the forestry trade to estimate timber volume and biomass as function of basal area and height (e.g. Dagnelie et al. 1985; Rondeux, 2010; Cannell, 1984). Given the well-known relationship between D and height (e.g. Feldpausch et al., 2011), this is not surprising. These stand level equations allow estimates of carbon to be made which are very close to those derived from tree by tree methods. Moreover, the stand allometric equations including the effect of D can be used to parameterize models and refine estimates that previously assumed a linear relationship between basal area and carbon.

Although our basal area data was obtained through enumeration of trees in inventory plots, previous studies have shown that figures for basal area, tree density and diametric distributions using relascopes are consistent with those based on the enumeration of trees in fixed area plots (e.g. Palley and Horwitz 1961; Grenier et al., 1991; Piqué et al., 2011). Generating information for basal area and tree density through these alternative methods will be faster, cheaper and easier than using full forest inventories in which the dimensions of all the trees in sampling plots are measured individually.

It is necessary to define which value of D will be used in the stand allometric equation. As expected from analysis of the allometric equations, the best results were obtained when the average diameter weighted by basal area was used. Results also show that it is possible to generate accurate values for the weighted average diameter to be used in these equations, based on a very small sample of large trees once the local relationship between tree size and density is known. In cases when $\overline{D_G}$ cannot be obtained, use of the simple average, or a conservative value for D, will systematically underestimate the figures of carbon. This is because overestimation of carbon in trees with D smaller than the average will be less than the underestimation corresponding to trees with D larger than the average. However, in fact it will be easier to estimate the weighted diameter average based on a sub-sample of large trees than the simple diameter average. If a consistent figure for the simple average of the diameter is needed, it will be necessary to sample around 30% of the trees to have average values with an error ± 20%, or up to 90% of the trees in the site to reduce the error to ±10% with 95% confidence (Appendix D); for the weighted average as shown above it will suffice to sample as few as 5% of the trees in an inventory site.

The relationship between the ratio $\overline{D_{G'}} / \overline{D_G}$ and tree density obtained here describes the conditions of the oak-pine forests in La Primavera and can be used to adjust diameter figures if new measurement plots are to be established in this site. In order to extend the approach to other locations it will be necessary to know how these relationships change for different species and site conditions. In the analysis of the stand density index Reineke (1933) indicated that the slope of the linear relationship between the logged quadratic mean diameter and density seemed to be consistent for different species, the parameter that seemed to vary across species was the intercept of this equation (Shaw, 2006). Thus, it is likely that equations similar to those presented in Figure 5.5 can be obtained for other vegetation types to follow the approach described here.

The system to monitor forests as part of REDD+ should include the use of both remotely acquired and ground level data (UNFCCC, 2010a). Reducing the effort to gather field data could be particularly important in this context since data generated at lower cost, could represent a considerable improvement where no previous data exists and estimates are based on default values. It has been shown elsewhere that members of rural communities with only a few years of formal education can rapidly learn and develop basic forest inventories (Skutsch, 2011). Local communities might be able to participate in the systems to monitor, report and verify information for the national REDD+ programs (UNFCCC, 2010a). If relascopic measurements are included as part of community monitoring it may help reducing the effort to acquire ground level data; this might help reducing the uncertainty of estimates as it will be easier to increase sample size. Based on the approach here presented it will be possible to develop field tables where basal area and D are the variables to read the value of carbon; this will emulate the existing tables to read timber volume as function of basal area and height (e.g. Dagnelie et al., 1985; Rondeux, 2010). In Appendix E we present one example of a basal area-D-carbon table for oaks using the equation of Návar (2009).

An important issue to keep in mind is that trees with a large D usually are not included in studies to generate allometric equations (Clark and Clark 2000; Chave et al., 2004; Zianis, 2008). This is a very important point to consider when using allometric equations given the importance of large trees as carbon stocks (e.g. Cairns et al., 2003; Bass et al., 2000; Pinard, 1995). It is critical to generate allometric equations by non-destructive methods that include valid ranges for trees with large D.

5.7. Conclusions

We explored the potential of using basal area as predictor of above ground carbon in trees as determined by different types of allometric equations. The configurations of the allometric equations show that the relationship between basal area and biomass and carbon is, in most cases, non-linear. This implies that in forests and stands with larger trees there will be more biomass and carbon than others with similar basal area but trees of smaller size. Previous carbon estimates using linear basal area to carbon equations may produce biased results if applied to stands with different D distributions. If there is not much variation in D across stands, the linear relationship between basal area and carbon will represent whether there are more or fewer trees of the same size. Stand allometric equations using basal area and weighted diameter as independent variables can be used to derive carbon figures per hectare; consistent figures for the weighted diameter can be obtained by measuring a few of the largest trees in site once the relationship between tree size and density is known. We consider that the use of these stand allometric equations is promising since basal area, tree density and the diametric distribution in a site can be quickly measured in the field. The uncertainty associated with use of non-local allometric equations and hence any systematic error between the true and estimated values should be assessed since this might be the highest contribution to the uncertainty of the results (Chave et al., 2004; Van Breugel et al., 2011); however, the development of local equations should be carefully considered.

5.8. Appendices

5.8.1. Appendix A. Basal area and carbon at constant diameter

When all the trees in a site have the same diameter then basal area will be given by equation A1 which is the basal area of a single tree times the density n in trees/ha. When equation A1 is substituted into equation 5.11 in the manuscript it can be seen that then carbon will be equal to the amount of carbon in an individual tree times the tree density in the site (Equation A2). Definitions of the variables used here correspond to those defined in Section 5.3 Basal Area and Carbon from Allometric equations.

$$\overline{G} = n * \frac{\pi}{40{,}000} * D^2$$
Equation A1

$$\overline{C} = K'*D^{x-2} * G = K'*D^{x-2} * n * \frac{\pi}{40{,}000} * D^2$$

$$= n * \frac{\pi}{40{,}000} * \frac{40{,}000 * K}{\pi} * D^2 * D^{x-2} = n * K * D^x$$
Equation A2

5.8.2. Appendix B. Error introduced by variation in tree density

Table 5.6 B.1. Variation in the error of the estimates when an error in tree density is introduced for the estimation of the weighted diameter (D_{G*}). The values indicate the error in comparison with carbon estimates based on the full enumeration of trees in the inventory plot (Mean values, in parenthesis the 95% range considering the percentiles 2.5% and 97.5%).

Sub-Sample (Size)	All Inventory Plots	Inventory Plots Classified by Tree Density			
		<10 trees/site (<111 trees/ha)	10-20 trees/site (111-222 trees/ha)	20-40 trees/site (222-444 trees/ha)	>40 trees/site (444-1100 trees/ha)
1	1.2% (-8.0%, 12.6%)	-0.5% (-7.0%, 9.4%)	2.3% (-5.1%, 11.8%)	-0.1% (-8.3%, 9.0%)	2.8% (-4.5%, 12.8%)
5	1.3% (-4.7%, 8.2%)	0.2% (-3.8%, 5.2%)	1.6% (-6.0%, 7.1%)	0.9% (-4.3%, 7.8%)	2.1% (-3.6%, 8.3%)
10	1.5% (-5.4%, 6.5%)		1.5% (-6.1%, 5.9%)	1.4% (-3.0%, 6.8%)	1.8% (-4.1%, 6.5%)
Variation in 'Density'	-7.9% (-80.0%, 21.4%)	-41.1% (-200%, 10.0%)	-4.7% (-28.6%, 25.0%)	0.4% (-17.4%, 14.3%)	-0.3% (-7.9%, 8.2%)

In order to assess the effect of introducing an error in the measurement of tree density we estimated the variation in results, with density values rounded to the closest 100 level in each site instead of the density value obtained from the forest inventory (e.g. if density in one site was 85 a value of 100 is used; if density was 255, a value of 300 is used). These changes produce a mean variation (error) of 8% for the density values (95% Range, from -80% to +21%).

The $\overline{D_{G'}}$ values are corrected using the rounded tree densities in the formulas presented in Figure 5.5; then carbon content and the errors in comparison with the forest inventory are recalculated. It can be seen that the 95% ranges for the errors widen slightly but there are no meaningful changes in the means. The effect would be relatively higher for areas with lower tree density and when the sub-sample of large trees is smaller.

5.8.3. Appendix C. Error introduced by estimation of diameter

Table 5.7 and Table 5.8 present the errors in the estimation of carbon, based on the use of the estimated $\overline{D_{G^*}}$ derived from local tree density and the sub-samples of large trees using the stand level equations in comparison with the values obtained using the stand level equation with the weighted diameter from the forest inventory. The objective is to identify the error introduced by the use of the method of large trees to generate figures of the weighted diameter. Table 5.7 shows the effect of introducing an error in tree density. These tables show that the differences between the two methods are small and unbiased with a symmetrical dispersion of errors; results also show a small sensitivity to errors in the measurement of tree density (Table 5.8).

Table 5.7 C1. Differences in carbon estimates obtained through the largest trees method, in comparison with carbon estimate based on the stand allometric equation using the data from the forest inventory (Mean values, in parenthesis the 95% range considering the percentiles 2.5% and 97.5%).

Sub-Sample (Size)	All Inventory Plots	Inventory Plots Classified by Tree Density			
		<10 trees/site (<111 trees/ha)	10-20 trees/site (111-222 trees/ha)	20-40 trees/site (222-444 trees/ha)	>40 trees/site (444-1100 trees/ha)
1	0.1% (-6.6%, 7.6%)	0.6% (-3.0%, 6.4%)	1.0% (-3.8%, 6.8%)	-1.7% (-7.7%, 7.5%)	1.1% (-6.0%, 8.5%)
2	0.0% (-5.8%, 5.4%)	0.2% (-2.0%, 3.8%)	0.9% (-2.5%, 4.6%)	-1.3% (-6.4%, 4.6%)	0.8% (-4.7%, 7.1%)
3	0.0% (-4.7%, 4.7%)	0.2% (-1.3%, 2.6%)	0.7% (-1.9%, 3.7%)	-1.1% (-5.1%, 3.8%)	0.6% (-4.0%, 5.8%)
4	0.0% (-3.9%, 3.9%)	0.3% (-1.1%, 1.9%)	0.5% (-1.4%, 3.0%)	-0.8% (-4.2%, 3.0%)	0.5% (-3.5%, 5.0%)
5	0.0% (-3.4%, 3.3%)	0.3% (-0.8%, 1.4%)	0.4% (-1.5%, 2.4%)	-0.7% (-3.6%, 2.5%)	0.4% (-3.2%, 4.3%)
6	0.0% (-2.8%, 2.9%)	0.3% (-0.4%, 1.1%)	0.3% (-1.5%, 1.9%)	-0.6% (-3.0%, 2.1%)	0.3% (-2.9%, 3.8%)
7	0.0% (-2.5%, 2.6%)		0.2% (-1.2%, 1.5%)	-0.5% (-2.6%, 1.9%)	0.3% (-2.7%, 3.3%)
10	0.0% (-1.8%, 2.1%)		0.2% (-0.7%, 0.9%)	-0.2% (-1.6%, 1.4%)	0.2% (-2.4%, 2.4%)

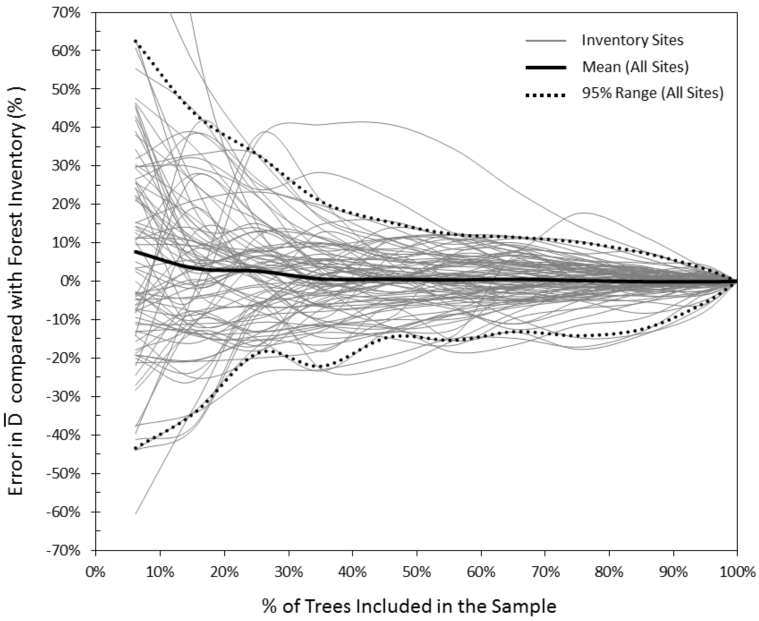
Table 5.8 C.2. Differences in carbon estimates obtained through the largest trees method in comparison with carbon estimate based on the stand allometric equation, basal area and weighted diameter obtained for each plot of the forest inventory. Tree density is rounded to the closest 100 density. (Mean values, in parenthesis the 95% range considering the percentiles 2.5% and 97.5%).

Sub-Sample (Size)	All Inventory Plots	Inventory Plots Classified by Tree Density			
		<10 trees/site (<111 trees/ha)	10-20 trees/site (111-222 trees/ha)	20-40 trees/site (222-444 trees/ha)	>40 trees/site (444-1100 trees/ha)
1	-0.2% (-6.8%, 7.8%)	-1.1% (-6.9%, 6.7%)	0.9% (-3.7%, 6.4%)	-1.6% (-7.5%, 7.9%)	1.1% (-6.1%, 8.6%)
2	-0.3% (-5.9%, 5.5%)	-1.5% (-6.4%, 4.1%)	0.7% (-2.9%, 4.4%)	-1.2% (-6.2%, 5.0%)	0.8% (-4.6%, 7.4%)
3	-0.2% (-4.4%, 4.6%)	-0.8% (-4.0%, 3.1%)	0.5% (-2.2%, 3.5%)	-1.0% (-5.1%, 3.7%)	0.6% (-3.9%, 6.2%)
4	-0.2% (-3.7%, 3.9%)	-0.8% (-3.6%, 2.3%)	0.3% (-2.4%, 2.9%)	-0.8% (-4.3%, 2.8%)	0.5% (-3.4%, 5.4%)
5	-0.1% (-3.3%, 3.4%)	-0.4% (-2.1%, 1.9%)	0.2% (-2.7%, 2.5%)	-0.6% (-3.6%, 2.4%)	0.4% (-3.0%, 4.8%)
6	-0.1% (-3.0%, 3.0%)	-0.4% (-2.0%, 1.6%)	0.1% (-2.9%, 2.4%)	-0.5% (-2.9%, 2.1%)	0.3% (-2.8%, 4.2%)
7	0.0% (-2.6%, 2.7%)		0.0% (-2.8%, 2.4%)	-0.4% (-2.3%, 1.8%)	0.3% (-2.6%, 3.8%)
10	0.0% (-2.2%, 2.7%)		0.0% (-2.3%, 2.5%)	-0.2% (-1.5%, 1.6%)	0.1% (-2.2%, 2.9%)
'Error' in Tree Density.	-7.9% (-80.0%, 21.4%)	-41.1% (-200%, 10.0%)	-4.7% (-28.6%, 25.0%)	0.4% (-17.4%, 14.3%)	-0.3% (-7.9%, 8.2%)

5.8.4. *Appendix D. Change in mean diameter with sampling intensity*

In order to identify the effort required to obtain a consistent value for the simple mean diameter ($\overline{D}$) in a measurement plot, we analyse the error in D depending on the percentage of trees considered for this estimation in comparison with the mean value obtained in the inventory. Trees were sampled systematically by sub quadrats in each inventory plot; Figure 5.7 shows the variation in simple D average in each measurement plot and how it changes and converges to the value of the inventory as more trees are considered; the 95% range of the errors is included. The values converge to the mean, however, the variation (i.e. potential error) is larger when fewer trees are considered. As mentioned before if 30% of the trees were sampled in the plots to obtain the simple average, the mean will be close to the real value however, the error would be ± 20%; in order to reduce error to ±10% with 95% confidence the sampling effort required would be 90% of the trees in the site. If stand level equations were to use mean D instead of D weighted by basal area, the sampling intensity would have to be high.

Figure 5.7 Change in mean diameter as a function of the percentage of the trees of the inventory plot considered.



5.8.5. *Appendix E. Example of a basal area-diameter-carbon table*

Table 5.9 shows the implications of the non-linear relationship between basal area and carbon as discussed in Section 5.2. As the slope or ratio m in equation 5.6 is a function of the diameter, it can be seen that for a given basal area, there will be a considerable variation in above-ground carbon content depending on tree size.

Table 5.9 Basal Area-D-Carbon Table for oaks using the equation published by Návar (2009) presented in Table 5.1 in the text (values in tC/ha).

Basal Area (m2/ha)	Diameter at Breast Height (cm) (weighted by basal area)													
	7.5	10	15	20	25	30	40	50	60	70	80	90	100	150
0.5	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.5	2.6			
1	1.8	2.1	2.5	2.8	3.1	3.4	3.9	4.3	4.6	5.0	5.3	5.5	5.8	
2	3.7	4.2	5.0	5.7	6.3	6.8	7.7	8.5	9.3	9.9	10.5	11.1	11.6	13.9
3	5.5	6.3	7.5	8.5	9.4	10.2	11.6	12.8	13.9	14.9	15.8	16.6	17.4	20.9
4	7.3	8.3	10.0	11.4	12.5	13.6	15.4	17.1	18.5	19.8	21.0	22.2	23.2	27.8
5	9.2	10.4	12.5	14.2	15.7	17.0	19.3	21.3	23.1	24.8	26.3	27.7	29.0	34.8
6	11.0	12.5	15.0	17.0	18.8	20.4	23.2	25.6	27.8	29.7	31.5	33.2	34.8	41.7
7	12.8	14.6	17.5	19.9	21.9	23.8	27.0	29.9	32.4	34.7	36.8	38.8	40.6	48.7
8	14.7	16.7	20.0	22.7	25.1	27.2	30.9	34.1	37.0	39.6	42.1	44.3	46.4	55.6
9	16.5	18.8	22.5	25.5	28.2	30.6	34.8	38.4	41.6	44.6	47.3	49.9	52.2	62.6
10	18.3	20.8	25.0	28.4	31.3	34.0	38.6	42.7	46.3	49.5	52.6	55.4	58.1	69.5
12	22.0	25.0	30.0	34.1	37.6	40.8	46.3	51.2	55.5	59.4	63.1	66.5	69.7	83.4
14	25.7	29.2	35.0	39.7	43.9	47.6	54.1	59.7	64.8	69.4	73.6	77.6	81.3	97.3
16	29.3	33.4	39.9	45.4	50.1	54.4	61.8	68.2	74.0	79.3	84.1	88.6	92.9	111.2
18	33.0	37.5	44.9	51.1	56.4	61.2	69.5	76.8	83.3	89.2	94.6	99.7	104.5	125.2
20	36.7	41.7	49.9	56.8	62.7	68.0	77.2	85.3	92.5	99.1	105.1	110.8	116.1	139.1
22	40.4	45.9	54.9	62.4	68.9	74.8	85.0	93.8	101.8	109.0	115.7	121.9	127.7	153.0
24	44.0	50.0	59.9	68.1	75.2	81.6	92.7	102.4	111.0	118.9	126.2	133.0	139.3	166.9
26	47.7	54.2	64.9	73.8	81.5	88.4	100.4	110.9	120.3	128.8	136.7	144.0	150.9	180.8
28	51.4	58.4	69.9	79.5	87.7	95.2	108.1	119.4	129.5	138.7	147.2	155.1	162.6	194.7
30	55.0	62.5	74.9	85.1	94.0	101.9	115.9	128.0	138.8	148.6	157.7	166.2	174.2	208.6
32	58.7	66.7	79.9	90.8	100.3	108.7	123.6	136.5	148.0	158.5	168.2	177.3	185.8	222.5
34	62.4	70.9	84.9	96.5	106.5	115.5	131.3	145.0	157.3	168.4	178.7	188.3	197.4	236.4
36	66.0	75.0	89.9	102.2	112.8	122.3	139.0	153.5	166.5	178.3	189.2	199.4	209.0	250.3
38	69.7	79.2	94.9	107.8	119.1	129.1	146.8	162.1	175.8	188.2	199.8	210.5	220.6	264.2
40	73.4	83.4	99.9	113.5	125.3	135.9	154.5	170.6	185.0	198.2	210.3	221.6	232.2	278.1

When all the trees have the same diameter, the weighted diameter and simple mean will be equal (e.g. in plantations).

6. The valuation of forest carbon services by Mexican citizens: the case of Guadalajara City and La Primavera Biosphere Reserve[14]

6.1. Abstract

Adequate demand for, and recognition of, forest carbon services is critical to success of market mechanisms for forestry-based conservation and climate change mitigation. National and voluntary carbon offsetting schemes are emerging as alternatives to international compliance markets. We developed a choice experiment to explore determinants of local forest carbon offset valuation. A total of 963 citizens from Guadalajara in México were asked to consider a purchase of voluntary offsets from the neighbouring Biosphere Reserve of La Primavera and from two alternative more distant locations: La Michilía in the state of Durango, and El Cielo in Tamaulipas. Surveys were applied in *market stall* sessions and online using two different sampling methods: the snowball technique and via a market research company. The local La Primavera site attracted higher participation and valuation than the more distant sites. However, groups particularly interested in climate change mitigation or cost may accept cost-efficient options in the distant sites. Mean implicit carbon prices obtained ranged from \$6.79-\$15.67/tCO_{2eq} depending on the surveying methodology and profile of respondents. Survey application mode can significantly affect outcome of the experiment. Values from the market stall sessions were higher than those from the snowball and market research samples obtained online; this may be linked to greater cooperation associated with personal interaction and collective action. In agreement with the literature, we found that valuation of forest carbon offsets is associated with cognitive, ethical, behavioral, geographical and economic factors.

6.2. Introduction

Given the public nature of environmental services, markets often fail to recognize their value, resulting in losses of the environmental assets providing the services (e.g. Bator, 1958, Samuelson, 1954, Landell-Mills and Porras, 2002; Stern, 2006). Public interventions and institutional arrangements are required to correct this policy failure and reconcile supply and demand of the services (Pagiola et al., 2002). Market-based mechanisms inspired by Coasean bargaining have emerged as new cost effective governance tools to deal with environmental problems (Coase, 1960; Voss, 2007).

Market mechanisms for environmental services, such as carbon sequestration in forests, may work better if they are, at least in part, private goods, creating some rivalry and excludability (Samuelson, 1954; Farley, 2010; Koellner et al., 2010). The Kyoto Protocol created a market for

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certified emissions reductions (CERs) from afforestation and reforestation projects under the Clean Development Mechanism. A global program is also under development through the UNFCCC to reduce emissions from deforestation and forest degradation (REDD+) where market mechanisms can be implemented (UNFCCC, 2010a, 2010b, 2012a). Demand for CERs has been created through the obligation on Annex I countries of the Kyoto Protocol to reduce emissions; however, demand for offsets is weakened by difficulties in reaching new emission reduction targets for the post 2012 period. This is particularly critical for carbon sequestration credits since these are considered temporary CERs. New market mechanisms are being developed, including domestic schemes in developing and emerging countries, and compliance markets under domestic laws in developed countries (Perdan and Azapagic, 2011; Sterk and Mersmann, 2011). Technical understanding and political support are required to harmonise the existing and emerging schemes (Perdan and Azapagic, 2011).

Parallel to international compliance markets, demand for carbon offsets has also developed in private voluntary markets (Hamilton et al., 2007). Momentum created by REDD+ negotiations under the UNFCCC has promoted an increase of the share of forest related projects in this market from 8 in 2009 to 25 $MtCO_{2eq}$/year in 2010 (Peters-Stanley et al., 2011), with these carbon credits now commanding a 43% share. Voluntary carbon markets as a whole are currently small, representing only 0.3% of total carbon traded (Ziegler et al., 2012); however, they send an important signal on actions needed to mitigate climate change (Linacre et al., 2011). International negotiations have been slow to develop an effective climate policy, but citizens can undertake immediate individual actions to mitigate climate change (Solomon and Johnson, 2009). However, individuals are largely unaware of offsetting as a means to mitigate climate change (Ziegler et al., 2012).

Study of demand for carbon, and other environmental services, is a critical area of research for design and successful implementation of policies geared towards funding forest conservation. In particular, market mechanisms based on predictable demand might increase the chances for successful implementation (Pagiola et al., 2002). The research presented here focuses on citizen valuation of forest carbon services in order to identify potential drivers for demand of carbon offsets and participation in voluntary markets. We developed a choice experiment which was applied to citizens of the Mexican city of Guadalajara. They were asked to consider offset purchase from the nearby Biosphere Reserve of La Primavera in competition with two alternative forest locations. The experiment had three objectives. Firstly, to assess how individual profiles of citizens were related to valuation of carbon offsets. Secondly, how alternative project locations were valued; and thirdly to examine how mode of application of the survey affected valuation. The chapter is organized as follows: firstly the literature on valuation of climate change efforts and forest carbon services is reviewed followed by a description of the context of our case study. Secondly the methodology and survey procedure are presented followed by results and discussion; and thirdly, in the final section we give our conclusions.

6.3. Literature Review

6.3.1. Valuation of Climate Change Mitigation

Integration of societal preferences into climate policy is an important challenge (Diederich and Goeschl, 2011), and a number of studies have addressed public valuation of climate change mitigation and emissions reductions. Johnson and Nemet (2010) review 27 published studies exploring willingness to pay (WTP) to mitigate climate change. Most of these used the contingent valuation method (CV). The range of WTP figures, standardized by Johnson and Nemet to present the information at the household level, ranges from $22 to $437 per year (median $135). WTP values presented in some of these studies on a carbon basis show values ranging from $5 to $28.6 (Lu and Shon, 2012), €25 (Brouwer et al., 2008), £24 (MacKerron et al., 2009) or €47 (Akter et al., 2009) per ton of carbon dioxide (CO_{2eq}). Nevertheless, these estimates need to be treated with caution due to possible bias of WTP in stated preference methods, and also because many of these studies targeted non representative sectors of the society with surveys based on current carbon prices (Diederich and Goeschl, 2011). Moreover, most of the studies reviewed by Johnson and Nemet (2010) came from developed countries and higher income groups, mainly in the United States and Europe, with another group of studies from Asia (Japan, Taiwan, South Korea and China).

In a CV study applied in Turkey at household level, Adaman et al., (2011) estimate that for payments of 20 Turkish Lira there was a 65% likelihood that the respondents would contribute to climate change mitigation by reducing energy related emissions. Carlsson et al., (2010) developed a valuation study targeting ordinary citizens in the US, Sweden and China. Their results show that Chinese citizens may be willing to pay $8.32 monthly per household for a 60% reduction in GHG emissions (purchase parity power US dollars). This is a lower WTP compared to US and Swedish citizens ($27.9 and $39.5 respectively); however, the share of WTP in relation to household income is similar in China and US, though both of these are lower than in Sweden (Carlsson et al., 2010). To the best of our knowledge there are no comparable studies valuing the benefits of forestry-based climate change mitigation in México or Latin America.

6.3.2. Valuation of Forest Carbon Services

The studies reviewed by Johnson and Nemet (2010) focused on valuation of climate change mitigation. However, they cover different ways of achieving this, including development of green electricity (e.g. Ethier et al., 2000; Bergmann et al., 2006), reduction of climate change impacts (e.g. Berk and Fovell 1999; Cameron, 2005), US ratification of Kyoto Protocol (Berrens et al., 2004; Li et al., 2004), general reduction of emissions (Carlsson et al., 2010), general emissions offsets (Brouwer et al., 2008), certified offsets and co-benefits (MacKerron et al., 2009), preservation of vulnerable species (Tseng and Chen 2008) and the use of ethanol as biofuel (Petrolia et al., 2010). Only the study of Layton and Brown (2000) was related to valuation of forests. These authors assessed the WTP for mitigation of climate change and reduction of the threat of losing vulnerable forested areas, and included forestry-based mitigation action as means to do this. Their results show that a population in the US (Denver, Colorado) perceived a cost in the loss of forests as a consequence of climate change (-$11.6 to -$98.5 depending on the extent and time horizon of the loss), and had a positive posture regarding use of forest-based strategies as means of mitigation ($11.5). Brey et al., (2007) developed a choice experiment to value Spanish forests, including carbon services, and showed that respondents from Catalonia would pay €11.79 annually to finance a program resulting in sequestration of 68,000 tCO_{2eq}. Koellner et al., 2010 used contingent valuation to explore the WTP of national and international firms in Costa Rica for different environmental services, including carbon sequestration, under a scheme of payments for environmental services (PES). Demand for carbon services among participants in their study (60 firms) was around 819 km^2 of forest for carbon sequestration in rainforests at a yearly payment of $65 per hectare (Koellner et al., 2010). These studies provide insights into valuation of forest carbon services, however, it is difficult to infer demand side valuation of carbon sequestration from them in terms of carbon ($\$/tCO_{2eq}$).

Other studies have valued carbon sequestration services in forests and from reforestation/afforestation practices using different approaches, but mainly focusing on the supply side by estimating provision costs and willingness of landowners to participate in carbon markets (e.g. de Jong et al., 2000; Richards and Stokes 2004; Brainard et al., 2009; Balderas Torres et al., 2010a; Markowski-Lindsay et al., 2011). While figures based on these approaches are necessary to estimate the potential provision of carbon sequestration, they need to be complemented with studies of the potential demand to evaluate the feasibility of market-based mechanisms.

6.3.3. Demand Side Drivers of WTP for Climate Change Mitigation

The most frequently cited explanatory variables of WTP in the studies reviewed by Johnson and Nemet (2010) relate to: environmental engagement, attitudes and beliefs, education, and perceived efficacy of the proposed policies. Other studies also report that WTP for climate change mitigation is related to environmental awareness (Adaman et al., 2011), perceived awareness and uncertainty of climate change impacts (Nomura and Akai, 2004; Akter and Bennett, 2009), payment vehicle type (Wiser, 2007), higher income and material well-being (Dietz et al., 2007; Li et al., 2009; Solomon and Johnson, 2009; Adaman et al., 2011), level of trust in the institutions implementing the activities (Adaman et al., 2011), younger age (Hersch and Viscusi 2006; Dietz et al., 2007; Li et al., 2009; Solomon and Johnson, 2009; Achtnicht, 2011; Adaman et al., 2011), gender (Viscusi and Zeckhauser, 2006; Dietz et al., 2007; Li et al., 2009; Solomon and Johnson 2009), the feeling of responsibility (Brouwer et al., 2008; Akter et al., 2009), the access to other local co-benefits (Longo et al., 2012), and, as expected from economic theory, it is negatively correlated with cost (Loomis and Ekstrand, 1998; Akter et al., 2009). Previous information related to carbon-offset prices and familiarity with offsetting practices are also positively related with WTP (Lu and Shon, 2012; Ziegler et al., 2012).

These observations on drivers of WTP coincide with meta-analysis research from environmental psychology, which concludes that attitude, behavioural control and moral norms explain a great proportion of pro-environmental behaviour (Hines et al., 1987; Bamberg and Möser, 2007). Studies on environmental values, as experiments in environmental economics, indicate that responses may represent an attempt to balance individual self-interest (mainly financial) with communal shared goals (Lynne, 2002; Ovchinnikova et al., 2009; Sautter et al., 2011). In an environmental economics experiment on carbon offsetting, Ovchinnikova et al., (2009) found that empathy and locus of control are strong factors influencing environmental decision-making; and can dominate the effect of pecuniary incentives. The constant reflection on individual actions regarding empathy and selfism related positively to environmental decisions, and when decisions were made without this reflection a profit maximization behaviour was favoured (Ovchinnikova et al., 2009).

As also noted by Ovchinnikova et al., (2009), Cai et al., (2011) indicate that including attitudinal questions and information before the valuation questions affects the result of stated preference surveys and WTP values. Thus environmental valuation studies should carefully consider inclusion of information or attitudinal questions before the valuation questions in stated preference studies, since this may significantly distort WTP values (Cai et al., 2011). This was reported earlier by MacMillan et al., (2006) who showed that provision of specific information, or the opportunity to deliberate, can affect results of environmental valuation studies. However, the provision of such information is critical when respondents are unfamiliar with the environmental good. This is not a minor issue as economic theory underlying stated preference methods requires preferences to be invariant and developed after the optimal gathering of information (Kahnemann, 1986). In the words of Gregory et al., (1993), practitioners of stated preference methods may play roles ranging from 'archeologists' to 'architects' of the environmental values. In addition to the information received, and reflections made as part of the studies and valuation experiments, respondents' familiarity with the environmental good under valuation can be directly related to previous experiences or behaviours (Cameron and Englin, 1997; Berrens et al., 2004).

Survey application mode may also be a factor determining the WTP obtained. As mentioned above, provision of specific information, or the opportunity to deliberate, can affect results of environmental valuation studies (e.g. MacMillan et al., 2006). Moreover, results from public good experiments show that when individuals are allowed to interact in person with other participants, this increases the potential for cooperation and collective action in situations where self-interested behavior might have been expected (Ostrom, 2000). This is an important point to consider because many environmental valuation studies have been applied online or are computer based due to the advantages of the internet for communication and sampling (e.g. Berrens et al., 2004; MacKerron et al., 2009; Diederich and Goeschl, 2011).

6.3.4. Background to selection of México as case study

México was chosen as a case study because the federal government has expressed the will to cut GHG emissions 50% by 2050 on a voluntary basis (PECC, 2008). Local markets for forest services independent of government budgets are envisioned as a national strategic policy (Presidencia 2007; CONAFOR, 2008). In México there is a small voluntary market for carbon offsets with most of the projects being developed in the southwestern region; for example, in the mid-nineties the Scolel Té project was set up in Chiapas as a research demonstration project using the Plan Vivo system (de Jong et al., 1995; Plan Vivo 2012). Since then a number of small projects have been developed by non-governmental organizations (NGOs). Carbon prices have ranged from 3.5 to 10 US$/tCO2eq (de Jong et al., 2004; Esquivel, personal communication). However, in general the population in México is not aware of these projects or of any individual options regarding the mitigation of climate change by offsetting, thus most offsets are sold internationally to companies or individuals.

La Primavera is an oak-pine forest located in the western part of México. It covers 30,500 hectares and was declared a protected area in 1980 (CONANP 2000), and a Man and Biosphere Reserve in 2006. It is adjacent to the metropolitan area of Guadalajara (4.4 million habitants). Guadalajara is the capital of the state of Jalisco which accounts for 6.6% of national gross domestic product (INEGI 2001). In general there is public awareness regarding environmental services provided by La Primavera; 65% of the general population has visited the forest at least once (Berumen, 2005) and when forest fires occur smoke and deterioration of air quality are widely noted in the city (El Universal, 2005). However, there has been no formal valuation assessment of the services and there is at present no system to channel financing for conservation or restoration activities directly from society. The ecological and economic dynamics between La Primavera and the metropolitan area of Guadalajara offer an attractive case to explore the potential for a local scheme to finance and enhance forest carbon services in the context of voluntary carbon markets.

6.4. Methodology

Choice modelling (CM) is a stated preference technique used in environmental non-market valuation and has been increasingly applied to elicit environmental non market values (Rolfe et al., 2000; Bennett and Blamey 2001). In addition to climate change mitigation, CM has also been used to address other aspects of forest valuation, such as rainforest conservation by Australian citizens (Rolfe et al., 2000); the design of forest management strategies for multiple use (Horne et al., 2005), the valuation of enhancements related to recreation (Christie et al., 2007) or to value biodiversity benefits (Meyerhoff et al., 2009).

In CM respondents are asked to choose between different options describing a specific intervention modifying the quality or level of provision of a specific environmental service or asset. The options describe different characteristics or attributes related to the environmental intervention including a monetary component (scenarios). Respondents are asked to choose which of the scenarios they prefer, for which they would have to pay a given amount. Usually two scenarios are presented in a choice set with a third opt-out option included allowing for participants who do not want to choose any of the alternatives presented. The opt-out represents the baseline for what would happen to the environmental asset if no specific action is taken. This allows estimation of welfare changes and WTP for the environmental services or goods.

CM is based on consumer choice theory and the random utility model (RUM) (McFadden 1974). The assumption in CM is that consumers' choices maximize their utility given the characteristics of the options presented and income restrictions (Bennett and Adamowicz 2001). We follow the method as described by Rolfe et al., (2000). The utility of the choice is represented by an observable component of the utility of individual and an error term:

$U_{ij} = V_{ij} + e_{ij}$ (Equation 6.1)

The observable component of the utility can be expressed as a function of the characteristics of the scenario proposed (Z_{ij}) and the characteristics of the individual (S_i):

$V_{ij} = V(Z_{ij}, S_i)$ (Equation 6.2)

Then the choices made will depend on the probability that the utility associated with one alternative is higher than for the other alternatives presented:

$P_{ij} = \text{Prob}\,(V_{ij} + e_{ij} > V_{ih} + e_{ih})$ (Equation 6.3)

For *j* different to all *h* in the choice set.

The RUM indicates that there is a stochastic or unobserved component in the utility, denoted by an error term. In multinomial logistic models (MNL), the utility function takes the form of a linear relationship on the parameters and variables with errors distributed according to a Gumbel distribution.

$P_{ij} = \exp(\lambda\, V_{ij})/\Sigma(\exp(\lambda\, V_{ih})$ (Equation 6.4)

Where λ is a scalar parameter normally set to one. Thus the MNL model can be written as:

$V_{ij} = \lambda(B_0 + B_1Z_1 + B_2Z_2 + ... + B_nZ_n + B_aS_1 + B_bS_2 + \ldots + B_mS_j)$ (Equation 6.5)

Where B_0 is a constant term that can be separated into alternate specific constants (ASC) for different options posed and B_1 to B_n and B_a to B_j are the coefficients of the vector of attributes and individual characteristics influencing the utility (Z_1 to Z_n and S_1 to S_j respectively). Implicit prices or part worth values can be obtained by dividing the coefficient of an attribute of interest by the coefficient of the monetary attribute.

$W = -1(B_{attribute}/B_{money})$ (Equation 6.6)

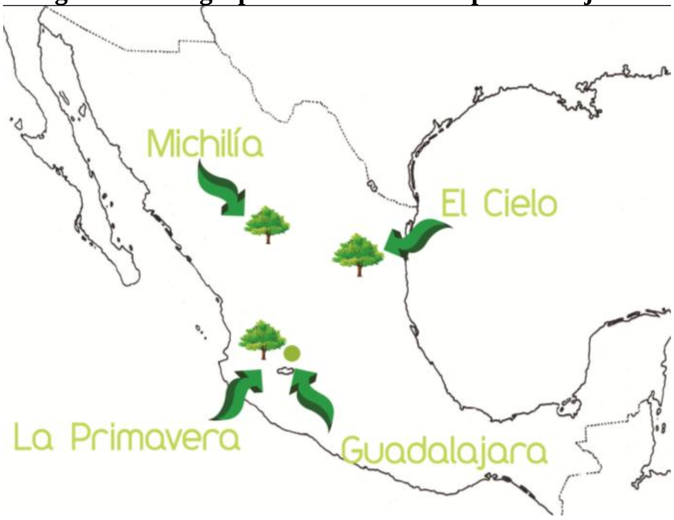
It is possible to compare the implicit prices from different models as the scalar terms cancel out when the implicit prices are obtained (Rolfe and Bennett 2001). In MNL models the errors are assumed to be independently and identically distributed (McFadden 1974; Louviere 2001). Violations to the assumption of the independence of irrelevant alternatives (IIA) imposed by MNL models can be detected through the test developed by Hausman and McFadden (Maddala 1983; Hausman and McFadden 1984). If MNL assumptions are violated, parameters and estimates obtained will be biased (Ben-Akiva and Lerman 1985). The IIA can be violated due to differences in tastes across the sample (heterogeneity), but this can be overcome by including socio-economic variables in the model in combination with alternative specific constants (ASC) (Bennett and Adamowicz 2001). Confidence intervals for the part-worths or implicit prices can be created following the method of Krinsky and Robb (Krinsky and Robb 1986; Haab and McConnell 2002); the differences between the implicit prices of two different samples considering a non-normal distribution can be analyzed through the Poe test, based on the complete combinatorial analysis of the implicit prices modeled (Poe et al., 2005; Ohdoko, 2008).

6.4.1. Survey design

In carbon markets, projects from different locations compete internationally to attract potential offset buyers. A basic assumption of market theory is that buyers will choose the least cost option, given similar products, aiming for cost efficiency. Although it is known that the effect of proximity might increase environmental valuation and produce spatial heterogeneity (e.g. Bateman et al., 2006; Johnston and Duke, 2009), previous research focusing on the valuation of forest carbon services and climate change mitigation has not thoroughly explored the implications of local projects in the design of market mechanisms. Bearing this in mind, we designed the CM experiment to identify how project location may influence valuation of carbon offsets. We focused particularly on valuation of carbon removal from the atmosphere through forest sequestration, which may contribute to achieving a sustainable rate of carbon assimilation (Daly 1990). In consequence the message given to participants in the survey focuses on the need to remove excess carbon from the atmosphere.

Three Mexican Biosphere Reserves were chosen as hypothetical project locations: La Primavera in Jalisco and two other Biosphere Reserves more distant from Guadalajara, La Michilía in the state of Durango, and El Cielo in Tamaulipas (Figure 6.1). These areas were chosen because they all offer opportunities to reduce emissions and to increase carbon stocks through conservation and afforestation activities resulting in reduction of loss of woody biomass (and hence carbon), forest growth, carbon sequestration and enhancement of forest stock. They have similar types of vegetation (oak-pine forests) and none has special or distinctive characteristics that might also be particularly valued by respondents (i.e. they are not associated to emblematic ethnic groups or charismatic animal species).

Figure 6.1 Geographic Location of Proposed Projects.



We invited the respondents to consider a hypothetical situation in which a NGO develops carbon sequestration projects in coordination with local landowners in each of the three areas, offering them the opportunity to buy offsets. The payment vehicle was a one-off voluntary and tax deductible payment to the NGO, to be used to finance conservation and reforestation activities to mitigate climate change. Thus the scenarios present three attributes which were defined after preliminary interviews and consulting with local experts. These were: the total cost that the respondents would be asked in order to remove a certain amount of carbon, the quantity of offsets and the project location.

The attributes and levels chosen were: three project locations (La Primavera, La Michilía, El Cielo); five payment levels ranging from \$23 to \$177 (\$23, \$50, \$77, \$131 and \$177, all figures are given in US dollars at an exchange rate of \$13 Mexican pesos per dollar); and four offset levels (2, 5, 9 and 19 tCO_{2eq}). These levels of the payments and carbon offsets bound the range of possible carbon prices to between \$1.2 and \$88/tCO_{2eq} when the maximum and minimum values are compared. These carbon prices are within a reasonable range given current and expected carbon prices for this kind of project (Galindo 2009; UN 2010). The quantity of carbon offsets is also similar to the *per capita* yearly emissions in México (6.8 tCO_{2eq}) (SEMARNAT 2009). Three focus groups and two pilot tests were carried out to verify that the survey could be understood, and to adjust the attributes and levels. The choice sets did not present the carbon price, but only the amount of offsets offered and the payment associated with each specific location. It is important to make sure that both costs and offsets are in relevant and reasonable ranges, since in CM the valuation levels are strongly determined by the selected levels of the attributes (Alpizar et al., 2001; Bennett and Adamowicz 2001). Taking into account the number of attributes and their levels, there are 60 possible combinations. Twelve choice sets were selected orthogonally and were presented in two questionnaires containing six valuation questions, with each question presenting two scenarios and an opt out option; each location appeared eight times in the choice sets.

In order to explore motivations, questions about previous environmental behavior, ethical attitudes and socio-economic and demographic characteristics were included. A question was asked about the most important factor when choosing, in order to identify the general preference of the respondents and whether it was focused on cost, carbon or location. People were asked about: the likelihood of purchase if the projects became operational; if they had ever estimated their carbon footprint; visited La Primavera; participated in reforestation campaigns or donated to environmental NGOs. Respondents also were asked to state if they agreed or not with the following statement: “I will buy carbon offsets because it is my responsibility to offset the emissions I generate”.

6.4.2. Survey application

The survey was applied using three methods: the first using the market stall technique allowing a direct interaction with respondents (MacMillan et al., 2002; MacMillan et al., 2006). The second sample was obtained applying the survey through the internet where the respondents were contacted using the snowball technique; and the third sample was also through the internet but using a market research company (e.g. Diederich and Goeschl 2011) in order to create a more systematic selection of respondents since in internet based surveys it is difficult to select randomly or obtain representative samples of the population (Thurston 2006).

For the market stall sessions, a list of neighborhoods within the metropolitan area of Guadalajara was used to select neighborhoods at random and ensure areas representing different socio-economic profiles were included. The city was divided into three zones depending on the distance to La Primavera (Close 0 to 3 km, Medium 4 to 6 and Distant 6 to 10 km). In each zone four neighborhoods of low, medium and high income levels were selected at random from the list as target areas for the market stall sessions.

For the second sample, the questionnaire was created in SurveyMonkey®. Links to access the survey were circulated through local universities, companies and social networks. When respondents finished the survey they were invited to send the link to their contacts. It was expected that this sample would have a larger share of highly educated people with higher environmental awareness, who would be more likely to distribute the link.

In order to reduce this potential bias, for the third sample a market research company with an extensive database of citizens was engaged, and instructed to contact a representative sample of the population. A specific profile of mid-high and high-income adults with high school education or above was selected. This group was chosen because they are economically most able to buy carbon offsets. The education filter reduced the cognitive burden of the exercise. Respondents with the desired profile were invited by email to answer the survey.

In all three methods the survey started by providing general background information. This was done in order to provide common information to all the participants on the characteristics of this type of project, which is unfamiliar to most people. The attitudinal questions were asked after the choice sets were presented. First general information regarding climate change, carbon sequestration by forests, and development of forest projects to mitigate climate change was explained. The information included: how carbon sequestration is quantified in a per tCO_{2eq} basis based on the content of carbon in biomass; production of oxygen from photosynthesis; the potential for reversal of benefits e.g. through fires; the implementation of projects by umbrella NGOs coordinating a group of landowners according to international standards; and the verification and certification of activities by third parties. The characteristics of project locations were described in terms of type of habitat, reserve size and opportunities to mitigate climate change: this information was presented in slides. Professional designers helped in the production of the visual support material. The slides were printed out and distributed among the participants during the market stall sessions. For the internet-based samples the slides were shown as an introductory presentation before the questions. The participants were told that variations in the costs within and across the sites may arise from differences in specific conditions such as soil productivity, slope and labour required; and respondents were also asked to consider their income available. To simplify the policy proposal we made no reference to cap-and-trade systems or the possibility to trade the offsets.

For survey application in market stall sessions, three sociology consultants and two environmental engineering undergraduate students were trained to become part of the research team. Local associations of residents and groups of neighbours from each area selected were contacted and invited to participate in the research and help in session organization. These associations frequently represent the community and participate in public affairs (e.g. in relation to local authorities); and in some cases provide public services (e.g. waste collection). The date, place, time and people invited to the sessions were agreed jointly by the research team and the associations to ensure a representative group of participants. The study was presented as research to evaluate the potential to develop climate change mitigation projects in forests in general. The objective was to gather from 8 to 10 persons for each session. During the sessions the research team was firstly introduced and the general information printed in the slides presented; then there was a space for questions and answers after which the questionnaires were distributed in unlabelled envelopes to be answered individually and anonymously. Finally there was a period for final comments and a small present was given to the participants for their time. In the internet surveys there was no space for questions and exchange of opinions other than an opportunity for respondents to write their comments. Questionnaires were all answered anonymously. The questionnaires for the market stall sessions were applied between July and September of 2010; the responses of the internet snowball sample were gathered from July 2010 to January 2011 and the surveys from the market research company were applied between from November 2010 and January 2011.

6.5. Results and Discussion

6.5.1. General Characteristics of the Samples

Table 6.1. Socio-economic and demographic characteristics.

	Market Stall	Internet Snowball	Internet Market Research
Age (years)	40.22	33.04	32.73
Gender (% of Females)	60.1%	48.9%	37.3%
Civil Status (% Married)	69.4%	37.0%	40.5%
Head Household (%)	54.2%	45.2%	46.8%
Size of Household (persons)	4.49	3.60	3.89
Respondent has Children (%)	72.1%	32.7%	43.0%
Education (Class)[a]	3.62	5.15	4.84
Income (Class)[b]	2.78	4.12	4.74
Daily income per capita ($/cap-day)[c]	7.7	15.9	15.6
Student (%)	10.8%	30.2%	24.7%
Employee (%)	34.3%	54.0%	49.4%
Domestic Occupation (%)	31.0%	7.3%	5.1%
Entrepreneur (%)	12.0%	25.9%	24.1%
Economically Active (%)	51.8%	75.9%	70.9%
n	332	473	158

[a] Education classes: 1) Elementary School, 2) Jr. High School, 3) High School, 4) Technical Studies, 5) Undergraduate, 6) Postgraduate
[b] Income classes 1) below $150; 2) $151-$307; 3) $308-$615; 4) $616-$1153; 5) $1154-$2307 and 6) above $2307 per household per month.
[c]Using the mid value of the income class, and the maximum value for class 6.

For the market stall sample 332 surveys were obtained; 473 surveys were obtained through Survey Monkey® and 158 through the market research company. Table 6.1 shows the general characteristics of the respondents for each sample. The internet market research sample was specifically targeted at the high income/high education segment while the market stall sample deliberately included a wider range of socio-economic conditions. This can be seen in the differences in education, income, economic activity and entrepreneurship of these two samples. The snowball sample shows a higher participation of students and younger respondents who may have relatively higher access to the internet; however, their socio-economic profile, aside from the marked difference in age and presence of students, is similar to that from the market research sample. There is a lower percentage of females in the market research sample; the contract for the company required a range between 40% to 60% for gender. Males responded faster to the invitation.

When preferences and previous environmental behaviour across the samples are compared, important differences appear (Table 6.2).

Table 6.2. Preferences and previous environmental behaviour.

	Market Stall	Internet Snowball	Internet Market Research
Focus on Cost (%)	28.0%	32.2%	30.4%
Focus on Carbon (%)	24.9%	31.3%	21.5%
Focus on Location (%)	47.1%	36.5%	48.1%
Positive Probability Offsetting (%)	83.7%	80.3%	84.2%
Assumes responsibility for own emissions (%)	84.8%	82.0%	70.9%
Previous Carbon Footprint (%)	7.7%	32.6%	7.6%
Participate in Reforestation (%)	53.8%	62.2%	56.3%
Visited La Primavera (%)	86.3%	88.8%	86.1%
Donation to Environmental NGOs (%)	13.8%	13.2%	18.4%
Protest, chose always Option A (%)	9.0%	5.9%	7.6%
Found the survey confusing (%)	11.1%	11.2%	8.9%
n	332	473	158

The snowball sample has a larger proportion of respondents who had previously estimated their carbon footprint, and hence have an initial interest in carbon rather than in project location. The market stall and the market research samples have comparable percentages in terms of previous environmental behaviour such as the knowledge of carbon footprint and participation in reforestation. Difference in previous donations arises from differences in socio-economic profiles within the market stall sample. The market research sample has practically the same percentage of visitors to La Primavera for this socio-economic group as that reported in an independent study based on random selection of households using individual surveying (86.1% vs. 85.9%) (Berumen 2005). When the percentage of visits for different income groups is considered in the market stall sample (below and above $615 per month), the values obtained are higher than those reported in Berumen (2005) (81.1% vs. 76.8% for the lower income group and 94.8% vs. 85.9% for higher income groups). The internet market research sample had a lower percentage of people assuming offsetting as a personal responsibility (about 10% lower); however, it had the highest percentage of persons previously donating to environmental NGOs. These donations may not necessarily be related to climate change mitigation projects and so do not require the assumption of responsibility over own emissions. These differences may indicate that in general there was a higher self-selection towards individuals feeling “more responsible” for their emissions in the market stall and snowball samples; and towards individuals with a higher degree of environmental awareness related to climate change affairs in the snowball one (i.e. carbon footprint previously estimated). The market research sample may offer a more representative view of the population of Guadalajara with a higher socio-economic profile;

however, some self-selection towards pro-environmental respondents could also be present, as reflected by the higher percentage of people who previously had donated to environmental NGOs.

6.5.2. *Protests*

The responses of the participants who found the questions confusing or who decided not to offset in any of the six valuation questions were excluded from the regressions of the MNL models[15]. These cases correspond to protests (as indicated by the participants' comments), incomplete questionnaires and those who stated that the questions were confusing in one of the debriefing questions; thus these observations were not considered in the analysis, in accordance with standard methods (e.g. Scarpa et al., 2009; Diederich and Goeschl, 2011; Longo et al., 2012). Results in the MNL models show the valuation of those accepting the offsetting scheme proposed. These results can be related to the potential demand for offsets from a marketing perspective for the citizens with these socio-economic characteristics. Any general welfare estimates based on these results need to consider this limitation. However, this approach is in agreement with previous studies valuing specific aspects of climate change mitigation targeting particular segments of the population and excluding protests (e.g. MacKerron et al., 2009; Scarpa et al., 2009). In this case the objective was to offer a general perspective on valuation of forest carbon sequestration in México and the effect of project location.

In order to investigate which factors are associated with higher chances of protesting against offsetting, Spearman's rho bivariate correlations were computed. The correlations are presented in Table 6.7 in the Appendices; they show different results for the three samples but in general the results agree with the reported determinants of WTP. Higher willingness to participate is positively related to income and economic activity, education, responsibility on emissions, younger respondents and previous visits to La Primavera, which can be considered as a proxy of familiarity with the site. For the market stall and snowball samples, when respondents are not primarily focused on cost but on the amount of offsets and project location, there is a higher chance to participate in offsetting. Interestingly for the market research company sample only one factor had a statistically significant correlation with protests: this factor showed that if respondents had previously donated to environmental NGOs they were more likely to protest against the scheme proposed. These protesting respondents may have no more income available for new environmental schemes. If we assume that the market research sample offers a more representative sample of the population it will be difficult to predict who will participate and who will not. This was reported previously by Solomon and Johnson (2009) who indicated that it was possible to assess the WTP for green electricity from those accepting to pay, however, determining who will actually pay for it was more difficult. The impossibility of identifying a profile of those protesting based on general individual characteristics supports the position that there will be other underlying ethical, social and moral factors driving this decision as suggested by Ovchinnikova et al., (2009), and Bamberg and Möser (2007). Nevertheless, the percentage of protests can be considered to delimit the maximum expected share of the population that may participate in offsetting.

[15] There were 67 protests and confused respondents in the market stall sample (20%), 78 in the snow ball (16%), and 19 in the market research sample (12%).

6.5.3. MNL models

Table 6.3 presents the MNL models generated for the three samples. In addition five more models were estimated to study the effect of particular characteristics of each sample (models 2, 3, 5, 6 and 8). As mentioned above, the market stall sample was stratified by household income, setting the limit at $615 per month. The snowball sample was divided into those who had previously estimated their carbon footprint and those who had not. A subsample of the market research sample was created in order to compare it with the higher income group of the market stall. The socio-economic and demographic characteristics of the subsamples are presented in Table 6.8 in the Appendices.

The MNL models include the attributes used in the choice experiment in combination with ASCs for each site option and individual characteristics as explanatory variables. An intercept term is included to capture the effect of missing variables. The inclusion of the variables indicating the preference for cost, carbon or location helps to reduce heterogeneity and increase model performance. All models are highly significant and with pseudo-R^2 values within the recommended levels, the coefficients are also significant and with the expected signs. The Hausman-McFadden test was performed on all the models by alternatively removing the different project locations and the opt out. No violations to the IIA restriction were found in Table 6.9 in the Appendices show the Chi squared values obtained.

The coefficients in Table 6.3 indicate that the utility derived from each project location changes depending on the general preference of the respondents. While La Primavera is the location more highly valued for those focused on location, as shown by coefficients in row 5 in Table 6.3(42% of the respondents[16]), other respondents may give up a project in La Primavera if they are focused on cost (row 5) (31% of respondents) or on carbon (row 10) (28% of respondents). This is shown by the negative signs of the coefficients for ASC2*Cost and ASC2*Carbon in all the models. This behaviour is consistent with market theory. People focused on cost or carbon gave up a project in La Primavera because it was not always the cheapest option, or that offering more offsets or offering them at lowest cost. It is important to note that the coefficient for La Primavera for the group focused on location (row 5 in Table 6.3) is always larger than those of the other locations for any of the three preference groups for all subsamples (rows 4, 6-12). This implies that *ceteris paribus* it will be more likely that the group focused on location, offsets their emissions in La Primavera, than those focused on cost or carbon buy offsets from other locations.

If a project is developed in La Primavera there would be a higher potential for participation amongst those focused on cost and carbon. People focused on carbon gave up a project in La Primavera because in some choice sets the alternative sites offered more offsets; if a project is created in La Primavera, as long as the project can continue generating offsets, the potential participants may be able to buy the same amount of offsets from La Primavera as from other locations. Likewise, if the cost of carbon from a project in La Primavera is similar to that from other projects, the group constrained by cost would choose this site. The valuation of La

[16] The percentage of the population focused on location, carbon or cost refers to the percentage of complete questionnaires (Table 6.5).

Primavera by the group focused on location may be a proxy of valuation of the local Biosphere Reserve by the local population of Guadalajara.

Table 6.3. MNL Models

		Market Stall			Internet Snowball.			Internet Market Research	
		1. All	2. Income Low	3. Income High	4.All	5. No Carbon Footprint	6. Carbon Footprint	7. All	8. Restricted
1	Intercept	-1.9229**	-2.0743**	-2.4600**	-1.8630**	-1.8828**	-1.8077**	-1.7590**	-2.0630**
2	Payment	-0.0095**	-0.0093**	-0.0060**	-0.0073**	-0.0070**	-0.0068**	-0.0113**	-0.0120**
3	Carbon	0.0827**	0.0633**	0.0940**	0.0718**	0.0679**	0.0771**	0.0935**	0.1070**
4	Michilía	0.7703**	1.1079**	1.7090**	0.9697**	0.9097**	1.5385**	0.8197**	0.9100**
5	Primavera	3.5831**	2.8432**	5.8040**	2.9809**	2.8586**	2.7787**	3.9712**	4.7160**
6	Cielo	-0.4990*	-0.1367	-0.5520	-0.2498	-0.6244**	-1.3980**	-1.0933**	-1.0720**
7	ASC1*Cost	0.8460**	0.6366*	1.2370**	0.9800**	1.0914**	0.5649+	0.9541**	1.3040**
8	ASC1*Carbon	0.8084**	0.6936**	0.8100**	1.1367**	1.2516**	0.8328**	1.1606**	1.0580**
9	ASC2*Cost	-1.6915**	-1.5327**	-1.5160**	-1.6384**	-1.6337**	-1.5132**	-2.6792**	-2.8510**
10	ASC2*Carbon	-1.6258**	-1.6166**	-2.0270**	-1.5667**	-1.6323**	-1.3876**	-2.3511**	-2.6080**
11	ASC3*Cost	0.5337**	0.4409+	0.8440*	0.1048	0.2311	-0.0521	0.2907	0.6470+
12	ASC3*Carbon	1.3092**	1.1415**	1.6330**	1.0468**	1.1764**	0.9162**	1.2690**	1.4590**
13	ASC3*Payment/ Carbon	0.1001**	0.1114**	0.0880**	0.1104**	0.1051**	0.1146**	0.1432**	0.1560**
14	ASC1*Payment/ Carbon		-0.0290+		-0.0524**	-0.0524**	-0.0490**		
15	ASC2*Payment/ Carbon	0.0230**	0.0241**	0.0270**				0.0115+	0.0210*
16	ASC1*Payment	0.0055*	0.0101**		0.0075**	0.0082**			
17	ASC1* Entrepreneur				-0.4215**	-0.4366**	-0.5422+		
18	ASC2*R.E.		0.9603**	-1.7170**	0.2377	0.5686**		-0.5751*	-1.0650**
19	ASC2* Entrepreneur				0.3844**	0.3985*			
20	ASC2* Domestic		-0.2780		-0.6472**	-0.4747+	-1.0024*		
21	ASC2*Married				0.5404**	0.4781**	0.5367*		
22	ASC2* Reforestation				0.1365		0.3724+		
23	ASC3*Visit Primavera				-0.3570+				
24	ASC1*Head H.H.						-0.6560**		
25	ASC1*Children						0.8904**		
26	ASC1* Domestic						1.7551**		
27	ASC3*RE						0.8515**		
28	ASC3* Donation						0.6375*	0.5234*	0.3480
29	Female*Payment/ Carbon		-0.0073						
30	ASC3*Carbon Footprint		0.9252+						
31	ASC1* Reforestation	-0.3370*		-0.6110*				-0.4225*	-0.4390+
32	ASC1*Married	-0.2395		-0.7240**				-0.3485+	-0.4240*
33	ASC2* Size H.H.	-0.0696*		-0.1630*				-0.9910**	-1.0180**
34	ASC3*Married			0.4520+					
35	ASC1* Donation							0.5630*	0.7380*
36	ASC3*Children							-0.6962*	-0.4770+
37	ASC2*Age							0.0361**	0.0360**
Model Statistics									
Model Chi square		1045.0**	522.8**	458.8**	1666.0**	1149.0**	545.6**	790.9**	680.9**
Valid cases (n)		4140	1962	1296	6498	4,248	2214	2430	1782
Pseudo R^2-Nagelkerke		31.0%	32.5%	41.4%	31.4%	32.9%	30.3%	38.6%	44.1%

The reference corresponds to the 'opt out' option, not buying offsets.
ASC1: La Michilia, ASC2: La Primavera, ASC3: El Cielo; +Significant at 90%; *Significant at 95%; **Significant at 99%.

6.5.4. Part-worth analysis

We used the results of the MNL models to estimate the implicit carbon price and benefits associated with each location and then followed the method of Krinsky and Robb, with 7,500 iterations to create 95% confidence intervals. The part-worths obtained from the models and the confidence intervals are shown in Table 6.4.

The market research sample has generally tighter confidence intervals, which may indicate that respondents from this group had fewer difficulties and had a more homogenous behaviour when answering the survey. This may be explained partly by previous experience in answering online questionnaires and because the sample had a more homogenous profile.

Table 6.4. Part-worths, implicit carbon prices and valuation of project locations.

Part-worths[a,b].	Market Stall			Internet Snowball.			Internet Market Research	
	1.All	2.Income Low	3.Income High	4.All	5. No Carbon Footprint	6.Carbon Footprint	7.All	8.Restricted
Carbon ($/t$CO_{2eq}$)	8.74 (5.96, 13.20)	6.79 (3.56, 10.25)	15.67 (9.50, 36.10)	9.77 (7.81, 12.54)	9.69 (7.21, 13.79)	11.29 (7.88, 17.95)	8.25 (6.20, 10.91)	8.92 (6.72, 12.27)
La Michilia ($)	81.4 (2.7, 267.5)	118.8 (30.1, 353.2)	284.8 (149.6, 740.8)	132.0 (71.5, 223.7)	129.8 (54.1, 259.3)	225.1 (109.9, 467.5)	72.4 (28.2, 122.1)	75.8 (23.5, 138.4)
La Primavera ($)	378.8 (229.2, 803.7)	305.0 (173.9, 668.1)	967.3 (536.6, 2611.1)	405.8 (311.9, 561.5)	408.1 (290.3, 631.4)	406.7 (273.0, 728.3)	350.7 (239.3, 514.2)	393.0 (256.9, 606.3)
El Cielo ($)	-52.7 (-143.2, 30.1)	-14.6 (-93.6, 88.4)	-92.0 (-395.2, 75.4)	-34.0 (-112.9, 39.2)	-89.15 (-180.5, -20.9)	-204.6 (-430.4, -79.2)	-96.5 (-173.4, -34.8)	-89.3 (-176.1, -21.5)

[a]The valuation of project sites corresponds to that of the groups focused on Location.
[b]Brackets denote 95% confidence intervals.

The implicit carbon price for the three full samples (models 1, 4 and 7) is similar, ranging from \$8.25 to \$9.77/tCO_{2eq}. Nevertheless, the figures show that deeper differences appear in the subsamples; in this case the mean carbon prices go from is \$6.79 per tCO_{2eq} to \$15.67 per tCO_{2eq} in models 2 and 3. The range of the utility derived from La Primavera also changes from \$350.7 to \$405.8 for the complete samples to \$305 to \$967.3 for models 2 and 3. These results show a positive correlation of the environmental valuation with income. The Poe tests for the implicit carbon price and the valuation of La Primavera (Table 6.4), are presented in Table 6.10 in the Appendices. When the three samples are compared there are no statistical differences in the implicit prices (models 1, 4 and 7). When the market stall sample is controlled for income the valuation of carbon in model 3 is statistically higher than that of models 2 and 8; but not higher than models 5 and 6 (snowball sample). In the case of the utility derived from La Primavera, it also produces statistically similar values when models 1, 4 and 7 are compared. However, in this case the values of model 3 are statistically higher than in all the other samples.

The utility derived from La Michilía for model 6 (snowball sample with previous knowledge of carbon footprint) can help to identify the effect of familiarity of personal carbon emissions. In the snowball sample those with previous knowledge of their carbon footprint have a slightly higher valuation of carbon than those who did not have it. The valuation of La Primavera among these two subgroups is almost the same (\$406.7 and \$408.1), however, the group with knowledge of their emissions valued La Michilia almost twice as much as their counterparts in model 5 (\$225.1 and \$129.8). Nevertheless, the only significant difference in the utility derived from La Michilía according to the Poe test is between model 5 and model 8 (higher income group in the market research sample) (Table 6.10 in the Appendices). This higher valuation associated with the familiarity of carbon accounts also agrees with previous research (e.g. Ziegler et al., 2012).

The higher income group in the market stall sample is the group with the highest valuation of carbon and La Primavera. In order to assess the effect of the survey application mode (i.e. in-person *versus* internet based mode), model 8 was prepared aiming to reduce the differences between the profiles of the subsamples used to build models 3 and 7. The subsample of model 8 has the same composition regarding gender, income, education, sense of responsibility on emissions and previous visits to La Primavera as model 3. However, there are still differences, these are factors mainly related with age: respondents from the market stall session tended to be older (mean of 41.2 *vs.* 32.2. years) (Table 6.7 in the Appendices). In comparison with the sample of model 7, the sample of model 8 had a higher percentage of respondents who felt responsible for their own emissions (83.3% vs. 70.9%) and fewer respondents focused on cost (23.1% vs. 30.4%). Although valuation of carbon and La Primavera improved from model 7 to 8, these modifications did not produce a meaningful increase comparable to that of model 3. The positive correlation of carbon valuation with income is consistent with economic theory, indicating that the usual figures of WTP may be strongly restricted by the ability to pay and income (e.g. Brouwer et al., 2008). Although the results are constrained by the limits of the experiment they indicate that citizens may pay carbon prices similar to those in the market (e.g. UN, 2010; Peters-Stanley et al., 2011), and they may be ready to participate in the market (Solomon and Johnson, 2009).

Although self-selection towards people with pro-environment views was present in the market stall sample this may have not been the main driver behind the higher valuation in model 3. The profile of respondents in the market stall sample is not as skewed towards persons with pro-environmental knowledge and behaviour as in the snowball sample, where self-selection was stronger. Moreover, when results from the snowball and market research samples are compared, there are no major differences in the part-worths, as can be confirmed by the Poe tests in Table 6.10 in the Appendices. People coming to the market stall sessions may have responded to the invitation primarily due to a higher disposition for cooperation in addition to an interest in environmental affairs. Bonds between neighbours are part of local social networks and interaction between them may be strong and frequent. Personal interaction and particularly group interaction may boost the sense of cooperation and collective action as mentioned in the literature (e.g. Ostrom, 2000). This feature can be used by NGOs promoting offsetting practices as means to engage with the public in these projects.

Table 6.4 shows the implicit prices for carbon and the valuation associated with the different project sites by the respondents focused on location; this allows us to obtain a proxy of the value of La Primavera for the citizens of Guadalajara[17]. Results indicate that the valuation associated with La Primavera as a one-off payment for project development in this site ranged from $305 to $967.3 per person among this group. When compared with the valuation of carbon offsets the valuation of the locations seem higher. The MNL models obtained can be used to explore which options would be accepted by the respondents depending on the cost, the number of offsets and location; the trade-off between carbon offsetting and the development of a project contributing to the restoration and conservation of a specific location can then be assessed. For instance the extra benefits experienced from a project in La Primavera for the respondents focused on

[17] As mentioned in the previous section the groups focused on carbon and cost may give up a project in La Primavera if cost-efficient options are not available locally, as shown by the negative signs for La Primavera in rows 9 and 10 in Table 6.3. We use the valuation figures from the group focused on location only as proxy for the local benefits of La Primavera.

location would be equivalent to the offsetting of 16 to 44 tCO_{2eq} in La Michilía, if the mean values in Table 6.4 are considered[18]. Since we only posed the possibility of one time offset purchase, these values are expressed in dollars per project per person. Had we asked instead for a yearly offsetting of emissions then the benefits could be interpreted as the yearly benefits. We decided not to ask for a yearly payment because of the unfamiliarity of the respondents with the offsetting schemes. Although respondents could make periodic purchase of offsetting motivated by previous positive experience (e.g. Welsch and Kuhling, 2009) this would have to be studied in more detail, and would also be conditioned by the possibility of the projects to deliver more offsets in the future.

6.5.5. Consistency of Choices

The way in which respondents choose in a CM can be used to test specific economic hypotheses (Alpizar et al., 2001; MacKerron et al., 2009). Evidence that respondents answered consistently with economic theory is represented by the difference in coefficients for La Michilía and El Cielo. When these coefficients are compared (row 4 with row 6 and row 7 with row 11, in Table 6.3), the coefficients of La Michilía imply higher chances of being selected in comparison with El Cielo. This is because on average the payments asked for La Michilía were lower than those asked for el Cielo. The value for La Primavera was in the middle: La Michilía ($83, S.D. 49), La Primavera ($86, S.D. 56), El Cielo ($105, S.D. 57). Thus the coefficients are consistent with an effort to minimize expenditure by those respondents focused on cost and location, when the local option (La Primavera) was not offered. The average carbon price of all the options included in the choice sets was \$17.3/tCO_{2eq} (S.D. 15.4, range \$2.5-\$65.4/ tCO_{2eq}). The design did not produce the same values for the three locations. The carbon prices for each location were: El Cielo \$8.0/tCO_{2eq} (S.D. 7.3), La Michilía \$12.8/tCO_{2eq} (S.D. 14.1) and La Primavera \$13.7/tCO_{2eq} (S.D. 21.9). This helps to test consistency in the choices of those who had a higher preference for carbon. When the coefficients in rows 8 and 12 in Table 6.3 are compared, it can be seen that in general they are higher for El Cielo than for La Michilía, which is to be expected considering that on average more offsets were offered in this site.

Economic theory suggests that buyers would choose the most cost effective option independently of the location. The results of this experiment show that offset buyers will make trade-offs between total cost and carbon price. However, for the levels offered in our experiment, an important proportion of the population will be willing to pay for local carbon offsets from La Primavera even when offsets from this location were not the cheapest. The potential premium for local carbon offsets in \$/tCO_{2eq} can be obtained after applying the survey in areas away from the project locations proposed.

6.5.6. General Preferences

As discussed above, whether the respondents are focused on cost, carbon or location determines how the choice sets were answered and how they valued carbon and the proposed project sites. Spearman's rho bivariate correlation coefficients were estimated between the selection of cost,

[18] These figures can be computed as (La Primavera- La Michilía)/Carbon.

carbon and location as the primary interest factor and individual characteristics of the respondents (Table 6.5).

Table 6.5. Significant Spearman's rho correlations between primary interest factor and individual characteristics.

	Focus on Cost	Focus on Carbon	Focus on Location
Age (years)		-0.126**	0.155**
Time living in the city (years)	-0.091**	-0.080*	0.156**
Civil Status (% Married)		-0.092**	0.112**
Head Household (%)		-0.071*	0.087*
Respondent has Children (%)		-0.072*	0.112**
Income (Class)	-0.068*		0.061+
Student (%)		0.112**	-0.099**
Entrepreneur (%)			0.082*
Economically Active (%)			0.071*
Positive Probability Offsetting (%)	-0.241**	0.123**	0.113**
Responsibility on emissions (%)	-0.186**	0.060+	0.117**
Previous Carbon Footprint (%)		0.110**	-0.118**
Visited La Primavera (%)	-0.085*	-0.094**	0.164**
Protest (%)	0.299**	-0.142**	-0.150**
n[a]	273	246	375

[a] There were 69 cases where this question was not answered.
+. Correlation is significant at 90% (2-tailed).
*. Correlation is significant at the 95% (2-tailed).
**. Correlation is significant at 99% (2-tailed).

Only significant correlations are shown in Table 6.5. The profile of the respondents focused on carbon show a larger presence of students and those who had previously estimated their carbon footprint. There is a negative correlation between focus on cost and income class and a positive one between income and focus on location. People who had visited La Primavera correlated negatively with the choice of cost and carbon but positively with location. There is also a correlation between protests and higher focus on cost, implying that these concerns were one of the reasons why some of these respondents chose not to buy offsets at all. The focus on carbon or location is negatively correlated with protests.

When respondents were focused on location, the valuation of La Primavera was higher, indicating that the respondents would be willing to pay more in order to get benefits additional to carbon removal. It could be hypothesized that these respondents behaved strategically and indicated they would pay more for La Primavera only because it was an exercise. The expected behavior was to choose cost-efficiently, thereby reducing their expenditure. However, there are indications that respondents responded rationally. In Table 6.5 it can be seen that the group focused on location is positively related with higher income and economic activity, which implies that they might indeed be more able to pay for a local project (e.g. Dietz et al., 2007; Adaman et al., 2011). It can also be seen that this group correlates positively with those who have lived longer in the city, have visited La Primavera and have children. These factors may indicate a higher familiarity with the site and the environmental services it provides which affects the valuation (e.g. Ziegler et al., 2012). Also, as described above, the respondents chose as expected when no local options were offered. Within the limits imposed by the experiment, this group of respondents would be willing to pay a premium on a per carbon basis in order to favour the restoration and conservation of La Primavera and access these benefits.

6.5.6.1. Reasons Why Respondents Would Not Participate

Participants were asked under which circumstances they would not participate if the projects became operational. Table 6.6 presents the responses of participants for the three samples. Economic factors are posed from two perspectives either if the respondent had no available income to participate or if the offsets were considered as too expensive; in this sense the existence of non-local mitigation options can give feedbacks to regulate local prices. Another group of factors relate to how the project would be implemented; participants indicated they would not participate if there was corruption or the project was not transparent. The access to information from the project will be easier in local projects; this can help to increase transparency. Another group of reasons against participation related to the type of policy proposed, there were protests against the participation of the public sector and market mechanisms. A group of respondents indicated they had other priorities in the allocation of their money.

Table 6.6 Reasons why participants would not buy offsets.

Reasons by Main Factor	**Market Stall**	**Survey Monkey**	**Market Research**
Project Related Factors: If there is corruption/ if it is not transparent; If there are no-results; I would participate if the project is local, if I receive frequent information of the project, and if it includes the need of the local communities and biodiversity conservation criteria…	42%	50%	46%
Economic Factor: If I do not have money/ if it is too expensive	41%	30%	46%
Factors Related to the Type of Policy: It is not my responsibility; I would not participate if it is a public project; I will reduce my emissions first; Protests against market-mechanisms	12%	16%	2%
Other Reasons: I would not have benefits/ I have other priorities	5%	4%	6%
Total comments (n)	98	177	204

6.5.7. Survey Application Modes

The application of surveys through market stalls permitted inclusion of a wider socio-economic profile in comparison to internet based techniques since it was possible to contact people with relative lower internet access (e.g. senior citizens, females occupied in domestic affairs). It also enabled participant’s questions to be answered. However, it was difficult to reach economically active middle aged men; this group was more easily contacted through the internet, at least for the groups with more years of formal education and higher income levels.

If the target group can be reached through the internet, this can reduce the cost of application and processing of the surveys. The cost of applying the surveys in person through market stalls including the design of the instrument and sampling strategy can range from around $8 to above $20 per person surveyed; plus the cost of any incentive that may be given to the participants in return for their time. Had we included more cities in the study the cost would have been higher. Comparatively the cost for each completed questionnaire online through market research companies may start at around $3 or less per person surveyed, depending on the specific requirements. The use of free internet surveying tools can reduce the cost of a study even more. However, if the researcher does not have an adequate method to contact the population of interest, the scope of the research may be limited. Another factor that needs to be taken into account, at least in certain areas, is personal security during application of surveys. This is now a major consideration in México and the use of the internet can help to overcome this problem.

The use of a market research company to contact a specific group through the internet helped to control self-selection and reduced the cost of the study. This method can be used to test specific hypothesis in environmental valuation, for instance studying the valuation of environmental assets by changing only one characteristic of the population of interest (e.g. age, occupation, distance to the asset). However, while using the internet can help to identify specific determinants of valuation it may generate consistently lower figures of valuation in comparison with methodologies using personal and group interaction. The characteristics of the population and objective of the study dictate the methodology used to approach the population of interest, which can significantly affect the results.

6.6. Conclusions

The results presented here show that valuation of carbon sequestration in forests is constrained by ethical, cognitive, behavioural and economic conditions such as: acceptability of the scheme, sense of responsibility, knowledge of emissions, previous visits to the forests and marked differences in income. Whether the respondents had a primary focus on cost, carbon or location affected their valuation of carbon and forests. The general model of choice, assuming that the respondent considered carbon offsetting as an acceptable scheme, would vary depending on the characteristics of the person. Firstly respondents would be focused on cost until they reach a certain degree of environmental responsibility and level of income. The preference for carbon or location would be affected by factors such as previous visits to the reserve and previous knowledge of personal carbon footprint. Additionally, selection of location as the primary factor of preference, within the scenarios posed in this experiment, is related to indicators of relatively higher economic wellbeing such as higher income class, higher economic activity, economic independence and entrepreneurship. Respondents focused on location may value the environment, and specifically La Primavera, not only for their benefit but also for that of their children. Results imply that the population of Guadalajara would in general accept the development of activities to mitigate climate change in La Primavera; and that if the project is developed in this location, other direct co-benefits would be enjoyed by the population.

Results also indicate that the choice of cost as a primary interest is negatively correlated with the assumption of offsetting as a personal responsibility. This is important because, at least at the international level, compliance carbon markets are designed with the assumption that they are tools for cost effective climate change mitigation. While economic incentives are important for enhancing the demand for carbon offsets, the creation of a sense of responsibility among the emitters may be a necessary precondition. The experiment shows that the results varied according to mode of survey application and the population sampled. The highest environmental valuation was obtained in the market stall sample and it was correlated with income. The possibility of interacting directly with the respondents helped to answer their questions during the experiment and the higher valuation may be linked to a greater cooperation associated with personal interaction and collective action.

Creation of a project to enhance forest carbon services in La Primavera might increase the probabilities of participating in a domestic market for forest carbon offsets among citizens from Guadalajara. The higher value that the residents from the city give to La Primavera is strongly related to proximity of the Biosphere Reserve. As an area for further research, it would be worth exploring how near a forested area should be to a population of interest in order to generate this extra valuation, or if the higher valuation of nearby forests is also present among residents from other regions in México. Studying these aspects may contribute to the design of the appropriate incentives for PES programs focused on carbon services, the design of domestic forest carbon markets built on local demand and the development of activities under REDD+.

6.7. Appendices

Table 6.7 Spearman's rho bivariate correlation between attitudinal and individual characteristics and protest responses.

	Market Stall	Survey Monkey	Market Research
Focus on Carbon	-0.117*	-0.188**	
Focus on Location	-0.120*	-0.130**	
Positive Probability of Offsetting (Probably Yes and Certainly Yes)	-0.233**	-0.339**	
Previous visit to La Primavera	-0.150**		
Age	0.299**	0.104*	
Years of Residence in Guadalajara	0.200**		
Income (mid class)	-0.112*	-0.102*	
High School Education	-0.142**		
Technical Studies	0.115*		
Employee	-0.175**	-0.111*	
Economically Active	-0.117*	-0.136**	
Responsibility on Emissions		-0.322**	
Student		-0.155**	
Previous Donation			0.190*

*. Correlation is significant at 95% (2-tailed).
**. Correlation is significant at 99% (2-tailed).
Correlations with positive signs indicate the contribution to protest against offsetting.

Table 6.8 Socio-economic and demographic characteristics of the sub-samples.

	Market Stall		Internet Snowball.		Internet Market Research
	2. Income Low	3. Income High	5. No Carbon Footprint	6. Carbon Footprint	8. Restricted
Age (years)	40.60	41.2	34.90	29.10	32.20
Gender (% of Females)	66.3%	49.5%	51.2%	44.2%	49.1%
Civil Status (% Married)	76.1%	60.8%	43.4%	24.1%	38.0%
Head Household (%)	54.0%	57.7%	45.6%	44.5%	40.7%
Size of Household (persons)	4.59	4.12	3.70	3.42	3.86
Respondent has Children (%)	78.5%	60.4%	38.2%	21.3%	39.8%
Education (Class)	3.07	4.62	5.10	5.24	4.82
Income (Class)	1.73	4.77	4.13	4.10	4.72
Daily income per capita	2.99	14.89	15.40	17.02	16.19
Student (%)	7.1%	15.5%	26.9%	37.2%	24.1%
Employee (%)	32.4%	50.5%	52.8%	56.9%	50.0%
Domestic Occupation (%)	44.0%	14.4%	7.7%	6.6%	5.6%
Entrepreneur (%)	7.7%	23.7%	28.7%	20.4%	24.1%
Economically Active (%)	45.1%	79.4%	77.6%	73.0%	71.3%
Focus on Cost (%)	31.3%	24.2%	32.0%	31.7%	23.1%
Focus on Carbon (%)	24.5%	23.1%	27.9%	38.7%	24.1%
Focus on Location (%)	44.2%	52.7%	40.1%	29.6%	52.8%
Positive Probability Offsetting (%)	85.2%	89.7%	86.1%	83.2%	88.9%
Responsibility on emissions (%)	86.2%	88.2%	83.5%	79.0%	83.3%
Previous Carbon Footprint (%)	5.5%	12.6%	0%	100%	7.4%
Participate in Reforestation (%)	51.7%	55.2%	60.5%	65.7%	56.5%
Visited La Primavera (%)	81.1%	94.8%	88.2%	90.2%	92.6%
Donation to Env. NGOs (%)	11.7%	14.7%	12.5%	14.7%	22.2%
Choose always Option A (%)	9.3%	7.2%	6.4%	4.9%	3.7%
Found the survey confusing (%)	8.8%	11.3%	7.8%	4.9%	6.5%
n	174	96	296	143	108

Table 6.9 Results of the Hausmann-McFadden test when the different options are removed.

Option Removed	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
La Michilía	9.3 (12), χ^2=21.02	3.9 (15), χ^2=24.99	1.1 (14), χ^2=23.68	7.6 (16), χ^2=26.3	6.1 (14), χ^2=23.68	0.6 (15), χ^2=24.99	4 (16), χ^2=26.3	4.3 (16), χ^2=26.3
La Primavera	7.5 (13), χ^2=22.36	17.0 (14), χ^2=23.68	0.2 (13), χ^2=22.36	2.9 (14), χ^2=23.68	2.4 (13), χ^2=22.36	1.8 (17), χ^2=27.6	0.4 (15), χ^2=24.99	7.6 (15), χ^2=24.99
El Cielo	5.8 (14), χ^2=23.68	3.8 (15), χ^2=24.99	1.6 (14), χ^2=23.68	1.6 (17), χ^2=27.6	5.2 (16), χ^2=26.3	0.0 (17), χ^2=27.6	2.0 (16), χ^2=26.3	3.3 (16), χ^2=26.3
Opt out	0.5 (17), χ^2=27.6	0.0 (19), χ^2=30.1	0.8 (18), χ^2=28.9	0.1 (21), χ^2=32.7	0.6 (19), χ^2=30.1	1.0 (22), χ^2=33.9	0.0 (21), χ^2=32.7	0.0 (21), χ^2=32.7

The number in parenthesis shows the degrees of freedom, χ^2 shows the critical value

Table 6.10 Results of the Poe test to identify differences in implicit prices.

Implicit Prices to be compared	Samples to be compared		Alternative hypothesis for the Poe test and γ value[b]		
	Price, Sample X	Price, Sample Y	$P_X=P_Y$	$P_Y>P_X$	$P_X>P_Y$
Carbon Price ($\$/tCO_{2eq}$)	(1) Market Stall	(4) Snowball	0.017*	0.690	0.293
	(1) Market Stall	(7) Market Research Company	0.020*	0.385	0.595
	(4) Snowball	(7) Market Research Company	0.015*	0.167	0.818
	(2) Market Stall, Low Income	(3) Market Stall, High Income	0.000**	0.994	0.005**
	(5) Snowball, No Previous Carbon Footprint	(3) Market Stall, High Income	0.004**	0.937	0.059
	(6) Snowball, Previous Carbon Footprint	(3) Market Stall, High Income	0.006**	0.825	0.169
	(8) Market Research, High Income	(3) Market Stall, High Income	0.002**	0.968	0.030*
	(8) Market Research, High Income	(5) Snowball, No Previous Carbon Footprint	0.019*	0.632	0.350
	(8) Market Research, High Income	(6) Snowball, Previous Carbon Footprint	0.011*	0.826	0.163
Utility derived from a project in La Primavera ($)[a]	(1) Market Stall	(4) Snowball	0.000**	0.589	0.411
	(1) Market Stall	(7) Market Research Company	0.000**	0.409	0.590
	(4) Snowball	(7) Market Research Company	0.000**	0.263	0.736
	(2) Market Stall, Low Income	(3) Market Stall, High Income	0.000**	0.987	0.013*
	(5) Snowball, No Previous Carbon Footprint	(3) Market Stall, High Income	0.000**	0.988	0.012*
	(6) Snowball, Previous Carbon Footprint	(3) Market Stall, High Income	0.000**	0.978	0.022*
	(8) Market Research, High Income	(3) Market Stall, High Income	0.000**	0.991	0.009**
	(8) Market Research, High Income	(5) Snowball, No Previous Carbon Footprint	0.000**	0.558	0.442
	(8) Market Research, High Income	(6) Snowball, Previous Carbon Footprint	0.000**	0.551	0.448
Utility derived from a project in La Michilía ($)[a]	(1) Market Stall	(4) Snowball	0.000**	0.765	0.235
	(1) Market Stall	(7) Market Research Company	0.001**	0.431	0.569
	(4) Snowball	(7) Market Research Company	0.000**	0.065	0.934
	(5) Snowball, No Carbon Footprint	(6) Snowball, Previous Carbon Footprint	0.000**	0.861	0.138
	(3) Market Stall, High Income	(6) Snowball, Previous Carbon Footprint	0.000**	0.315	0.685
	(2) Market Stall, Low Income	(6) Snowball, Previous Carbon Footprint	0.000**	0.845	0.155
	(8) Market Research, High Income	(6) Snowball, Previous Carbon Footprint	0.000**	0.987	0.013*

[a].Respondents focused on location.

b.The statistic of the Poe test (γ) can be considered as the p-value (Ohdoko, 2008)

*The alternative hypothesis can be rejected at 95% confidence level.

**The alternative hypothesis can be rejected at 99% confidence level.

7. Valuation of forests carbon services and co-benefits for the design of local carbon markets[19]

7.1. Abstract

Existing carbon markets are not designed to stimulate international demand for forestry carbon credits and thus fail to value forest climatic services. Domestic carbon markets are emerging in many countries and may be more effective in this regard. We use a choice experiment to investigate public valuation of forest carbon offsets in a domestic market in México. Results show that citizens would pay higher prices for offsets from projects closer to their homes. When offsets from local projects are not available, citizens base their decisions on standard cost-efficiency criteria as expected. Proximate forests maximize a range of local co-benefits such as environmental services, regional affiliation and recreation. Drivers of valuation are related to factors such as sense of responsibility, previous knowledge of emissions and previous visits to the sites. Market mechanisms are often used as tools to minimize the cost of climate change mitigation; however, if the civil preferences for mitigation action are taken into account, domestic carbon markets can be designed to capitalize this preference for local mitigation and thus increase the valuation and demand for forest carbon credits, maximize local co-benefits and welfare and augment the public acceptability of such policies.

7.2. Introduction

Forests offer cost-efficient ways to reduce emissions, to increase carbon removals and to contribute to climate change mitigation (Stern, 2006; Strassburg et al., 2009; Canadell and Raupach, 2008). However, existing carbon markets are not designed to stimulate the international demand for forest based carbon credits and are thus failing to realize the full value of forests in climate change mitigation. Forestry-based carbon sequestration credits are capped and regarded as temporary under the Kyoto Protocol (UNFCCC, 2002; UNFCCC, 2004). Because of this, they have been excluded from the European Union Emission Trading Scheme (CEC, 2003), the largest compliance carbon market in the world (Peters-Stanley et al., 2011). Forest carbon projects perform better in the voluntary market where they accounted for about 40% of the volume in 2010 (Peters-Stanley et al., 2011); however, the scale of this market is minimal (0.02% of global carbon traded) (Peters-Stanley et al., 2011). There is much optimism about the potential to realize forests climate services through the mechanism to reduce

[19] The material presented in this chapter has been submitted to be considered for publication as Balderas Torres, A., MacMillan, D.C., Skutsch, M., Lovett, J.C. Valuation of forests carbon services and co-benefits for the design of local carbon markets. The Corollary to this Chapter was not included in the aforementioned submission.

The results showed in the corollaries to Chapters 7 and 8 will be presented as a conference paper, Balderas Torres, A. ‘Demand and participation required for a local market for forest carbon services between La Primavera and Guadalajara’ at the 9th Congress of the Mexican Association of Rural Studies to be held from the 5th to 8th of March 2013 in Guadalajara, México.

emissions from deforestation and forest degradation in developing countries (REDD+) being negotiated under the United Nations Framework Convention on Climate Change (UNFCCC). However, it is not yet known how international demand for REDD+ credits will be created.

In the last few years voluntary measures and national policies have grown in importance in the climate regime. Developed and developing countries have communicated their domestic commitments and mitigation actions to the UNFCCC (UNFCCC, 2012a) including, in many cases, voluntary emission reduction targets and market-based policies (e.g. Sterk and Mersmann, 2011). These new market mechanisms may provide opportunities to finance forest carbon projects; but to be effective, markets need to stimulate the demand and valuation of carbon at levels that might ensure their provision. This research aims to investigate drivers of the public valuation for forest carbon services in domestic markets, seeking to identify elements that will enhance implementation of local and international climate policies related to forests. For this, the valuation of carbon removals by forests and spatial preferences for project development is assessed in the context of a hypothetical domestic market in México, using a Choice Experiment (CE) (e.g. Hoyos, 2010). México is a developing country with a high degree of urbanization and industrial activity and with a long-standing policy on payments for forest environmental services (PES) (Muñoz Piña et al., 2008). México was selected as a case study because it has adopted a voluntary target to reduce its emissions by 50% by 2050, with a substantial contribution from the forestry sector and market-based mechanisms (PECC, 2008; CONAFOR, 2010). This chapter is structured as follows: first background information on co-benefits of climate policy and environmental valuation is presented; this is followed by the description of the methodology and the main results; finally the discussions and conclusions are presented.

7.3. Background

Market-based mechanisms are used as part of climate policies because they help to reduce the cost of mitigation by searching for cost-efficient activities. According to standard market theory, buyers should prefer options offering more carbon offsets at the lowest cost. However, mitigation activities also generate co-benefits (IPCCC, 2001; Pearce, 2000) such as health benefits from reduced exposure to air pollution (Nemet et al., 2010), or environmental services from forests (Elabakidze and McCarl, 2007; Angelsen et al., 2009) that could change the results of cost-benefit analyses when their value is factored in policy evaluation (Pearce, 2000; Glenk and Colombo, 2011). For instance, options identified as most cost-efficient in cost curves, would be viewed less favorably if the value of co-benefits is considered (e.g. health, landscape, biodiversity, etc.) (Glenk and Colombo, 2011; Moran et al., 2008). The magnitude of co-benefits may be even higher than mitigation costs (Pearce, 2000; Nemet et al., 2010) and climate benefits (Glenk and Colombo, 2011; Pearce, 1992); this can be expected since the co-benefits are perceived locally and in the present while benefits of climate change mitigation will be global and appear mostly in the future (Pearce, 2000). Previous estimates in the United Kingdom and Norway indicated that local co-benefits of mitigation actions outweighed climate benefits from 10 to 20 times (Pearce, 1992). Thus, focusing only on the direct cost and benefits of mitigation actions to identify cost efficient solutions may prevent the efficient allocation of resources (Glenk and Colombo, 2011; McCarl and Schneider 2001; Plantinga and Wu, 2003). Climate policies should then aim to maximize the co-benefits (Pearce, 2000; Glenk and Colombo, 2011). International demand for offsets may be influenced from evaluation of trade-offs made by potential buyers between cost-efficient options elsewhere and valuation of co-benefits of local action (Pearce 2000).

The inclusion of co-benefits adds arguments in favour of implementing climate policy (Kousky and Schneider, 2003); however, it will not necessarily increase the chances of reaching globally binding mitigation agreements since countries can undertake local actions irrespective of the outcome of the negotiations (Finus and Rubbelke, 2008). This is an important challenge for potential providers of carbon credits targeting the global markets since a large part of the demand relies on compliance with such legally binding agreements. Recently the value of carbon credits in the Clean Development Mechanism has reached an all-time low (Krukowska and Carr, 2011), this is not surprising considering the difficulties of reaching an agreement for an ambitious emissions reduction target that might incentivize carbon demand for the second period under the Kyoto Protocol. Although the EU is on the way to comply with its targets under the Kyoto Protocol, major economies such as the United Kingdom, Germany and France (and 14 more European countries[20]) will base their mitigation efforts solely on domestic actions (EEA, 2011). The low demand for credits in international markets derives from low mitigation targets under the Kyoto Protocol and reduced industrial activity associated with the recent economic crises; moreover, poor capacity to enforce compliances is a weakness of international market-based mechanisms (e.g. Schelling, 1997; Aldy et al., 2003). However, this scenario is also consistent with discussion on consideration of climate policy co-benefits. In this context offshore offsetting in international carbon markets can be regarded as costs or lost opportunities to increase local welfare in the financing countries (Pearce, 2000; Krook-Riekkola et al., 2011); thus as the implementation of domestic policies advance, it can be expected that demand for carbon in international markets might be reduced.

In terms of global welfare, co-benefits are relevant wherever they are generated (Butraw and Toman, 2000) and may be higher in developing countries (Nemet et al., 2010). Considering this, developing countries should assess the role of co-benefits in domestic climate policy and identify the best means to achieve them (OECD, 2002). It is doubly important that countries aiming to develop local market mechanisms evaluate the potential for local demand and identify the features to be included into the institutional framework of these schemes that help to maximize demand for carbon and local welfare; this is important for countries adopting internal emissions reduction targets which would need to consider the trade-offs between selling the cheapest offsets abroad or promote their purchase by local actors.

The value of co-benefits of mitigation can be accounted for directly in economic figures in the cases when their value can be captured in existing markets (e.g. energy savings) (Pearce, 2000); however, ad hoc policy mechanisms are required to capture the value of co-benefits when they

[20] Countries basing mitigation on domestic action: Sweden, United Kingdom, Lithuania, Poland, Iceland, France, Germany, Greece, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Romania, Slovak Republic, Croatia, Liechtenstein. Countries basing mitigation on domestic actions and Kyoto Mechanisms: Austria, Belgium, Finland, Ireland, Luxembourg, Netherlands, Portugal, Slovenia, Norway, Switzerland, Denmark, Italy, Spain. Countries with no targets in the Kyoto Protocol: Cyprus, Malta and Turkey (from EEA, 2011).

are public goods for which there are no mechanisms to compensate those bearing the cost of mitigation (Pearce, 2000). In these cases, environmental valuation techniques can generate figures of willingness to pay (WTP) that can be used in policy design and evaluation. Non-market valuation techniques such as contingent valuation and choice experiment (CE) have been used to obtain figures of environmental values. Previous studies using CE have approached the valuation of forests and the geographical influence in environmental valuation (Rolfe et al., 2000; Brey et al., 2007; Bateman et al., 2006; Abildtrup et al., 2011) and have also valued climate change mitigation efforts (e.g. Glenk and Colombo, 2011; MacKerron et al., 2009; Akter et al., 2009). Research has reported the preference for local environmental improvements for aspects such as forest recreation (Abildtrup et al., 2011), water quality (Morrison and Bennett, 2004; Brouwer et al., 2010) and biodiversity services (Garrod et al., 2012). This is to be expected since proximity allows access to non-use and higher use benefits (Bateman et al., 2006; Johnston and Duke, 2009) that decay with distance (e.g. logarithmically) (Bateman et al., 2006). Distance decay patterns allow identification of the relevant economic markets for environmental valuation (Bateman et al., 2006).

Results from one or many environmental valuation studies can orientate decision makers through benefit transfer (Bennett, 2006; Wilson and Hoehn, 2006; Woodward and Wui, 2001; OECD, 2002; Pearce, 2000). This approach can be used also to compare the changes in environmental valuation across different populations and geographical scales (Morrison and Bergland, 2006). In order to test for geographical variations in WTP for environmental improvements, separate models can be estimated for different sites of interest (Willis and Garrod, 1999; Birol et al., 2006; Campbell et al., 2009). The comparison of implicit prices obtained through CE and results of WTP are the most common method to test the validity of the transfer of benefits by comparing the valuation at different scales and sites, this can be made by comparing the confidence intervals (e.g. Van Bueren and Bennett, 2004) and the statistical distribution of the prices or WTP (Poe et al., 2005; Morrison and Bergland, 2006). The potential for benefit transfer is increased when there is higher correspondence between the areas under consideration in terms of the environmental resource being valued (biophysical characteristics and scale of environmental improvements), the market valuing it (characteristics of the population) and the welfare measures (property rights and policy settings) (Loomis and Rosenberger, 2006; Bennett, 2006, Boyle and Bergstrom, 1992; Rosenberger and Phipps, 2007; Johnston and Duke, 2009; Morrison and Bergland, 2006). This is supported by the review of studies by Morrison and Bergland (2006) who found converging results in the transference of benefits when the characteristics of the environment and populations involved were more alike; however, there was less support for the transferability of values between those living close and apart from study areas showing a geographical heterogeneity (Morrison and Bergland, 2006).

Despite the heterogeneous spatial preferences for environmental benefits, this has not been used to compare the valuation of local versus non-local forestry offsets in the context of carbon market mechanisms. Moreover, the valuation of forestry-based climate mitigation actions has been scarcely studied from the demand side. The review of 27 published studies valuing climate mitigation efforts by Johnson and Nemet (2010) shows that most of the published studies have valued mitigation through non-forestry-based approaches; only one study by Layton and Brown (2000) approaches forests indirectly through the valuation of the reduced climate related damages to vulnerable forests. This work aims to contribute to this area by using the results from a CE to compare the valuation of local and non-local forest offsets by citizens in México and discuss the implications for the design of climate policies, particularly domestic market-based mechanisms.

7.4. Methods

CE is a stated preference method used for environmental valuation (Hoyos, 2010); it requires the design and application of questionnaires and the development of econometric models. The technique is based on welfare, demand and consumer theories and the random utility model (Lancaster, 1966; McFadden, 1974). CE permits identification of the valuation of changes in the environment (goods or services) or policies modifying them. In CE participants are presented with alternative scenarios that are described in terms of different characteristics or attributes from which they should select the scenario they prefer. Usually one of the attributes is a component describing the cost to the participant of achieving the proposed change in the environment, thus the choices can be related to the WTP of the participants for that environmental change to happen. It is assumed that choices made in a CE are those maximizing the utility of the participants (Bennett and Adamowicz, 2001). The choices are modeled in an econometric model of individual utility. The random utility model indicates that there is an error term; the multinomial logit model (MNL) commonly used in the CE assumes that this stochastic term follows a Gumbel distribution (McFadden, 1974; Louviere, 2001). Due to this assumption a MNL model will be valid only if it complies with the restriction of independence of irrelevant alternatives (IIA) which can be assessed via the Hausman-McFadden test (Hausman and McFadden, 1984; Maddala, 1983). The utility function is usually depicted as an additive function where the independent variables are the attributes of the experiment, alternative associated constants (ASC) and individual characteristics and the dependent variable is the choice made by respondents. The inclusion of ASC in combination with individual characteristics can help to overcome the restrictions imposed by the IIA assumption. In CE it is possible to evaluate trade-offs between the different attributes shown to the participants (Bennett and Adamowicz, 2001), and since one of these attributes is a cost component, thus the marginal value, implicit prices or part-worths can be obtained when the parameter of a given attribute is divided by that of the cost attribute (Rolfe et al., 2000). For more details on the CE method please refer to Hoyos (2010) or Rolfe et al., (2001).

7.4.1. Survey Design and Analysis

Participants in the CE were asked to consider the voluntary purchase of forest carbon offsets to remove atmospheric carbon and mitigate climate change. The mechanism proposed was through a one-time tax-deductible payment to an environmental non-governmental organization (NGO). It was explained that the NGO was collaborating with forest holders and communities in the development of carbon sequestration practices complying with international standards; this is common in projects already under development in the voluntary market in México (e.g. the Scolel Té project (Plan Vivo, 2012)).

Three attributes were included in the CE: the project location, the number of offsets to be bought and the total cost to be paid. Three Biosphere Reserves were selected as hypothetical project locations: La Michilía in the state of Durango, La Primavera in Jalisco and El Cielo in Tamaulipas (UNESCO, 2011). The reserves selected were chosen because they all offer opportunities to reduce emissions and to increase carbon stocks, they have similar types of vegetation (oak-pine forests) and none has special or distinctive characteristics that might also be particularly valued by respondents (e.g. emblematic ethnic groups or charismatic animal species). Five payments from $23 to $177 ($23, $50, $77, $131, $177)[21] and four offset levels from 2 to 19 tCO_{2eq} (2, 5, 9 and 19 tCO_{2eq}), were used. Local experts participated in the selection of attributes and levels that were tested in two pilots. The values selected are reasonable considering expected carbon prices for these projects and per capita emissions in México (UN, 2010; Galindo, 2009; SEMARNAT, 2009). This is important because the selected levels strongly determine the valuation levels obtained (Bennett and Adamowicz, 2001; Alpizar et al., 2001). Choice sets were prepared following an orthogonal main effects design that generated 25 cards, these were combined into twelve choice sets: two questionnaires including six sets each were prepared each choice set presented two options for the purchase of offsets and one ‘opt out’ option.

The survey started by providing background information and included the choice sets, debriefing, behavioral, attitudinal and socio-economic questions. Professional designers helped to present the information in the most accessible way to respondents. The background information included: how carbon sequestration is quantified in forests; the potential for reversal of benefits e.g. through fires; the implementation of projects by an umbrella NGO coordinating a group of landowners according to international standards; and the verification and certification of activities by third parties. It was mentioned to the participants that variations in the costs within and across the sites may arise from differences in specific conditions such as soil productivity, slope and labour required. The experiment made no reference to emissions trading. The possibility of carbon trading linked to cap-and-trade system was not mentioned as this was an unfamiliar topic for the respondents, which would have added confusion. Another reason for this was because the experiment targeted citizens who could be considered as the ‘final users’ of the offsets from the consumption perspective, thus these credits are retired from the market once they have been bought. Before presenting the choice sets respondents were asked to consider the money they require for all their other expenses (cheap talk) (Carlsson and Martinsson, 2001). In the debriefing questions respondents were asked if the survey was confusing or not, and for the most important attribute when making choices. This question helped to deal with the issue of non-attendance of attributes (Scarpa et al., 2009). Questions related to previous behavior included whether the person had earlier estimated his/her carbon footprint, bought offsets, visited the biosphere reserves, participated in reforestation campaigns or donated to environmental associations. Other questions asked for the factors for and against offsetting, the valuation of local forests, whether or not respondents considered offsetting a personal responsibility for personal emissions and if they had preferred an alternative project location.

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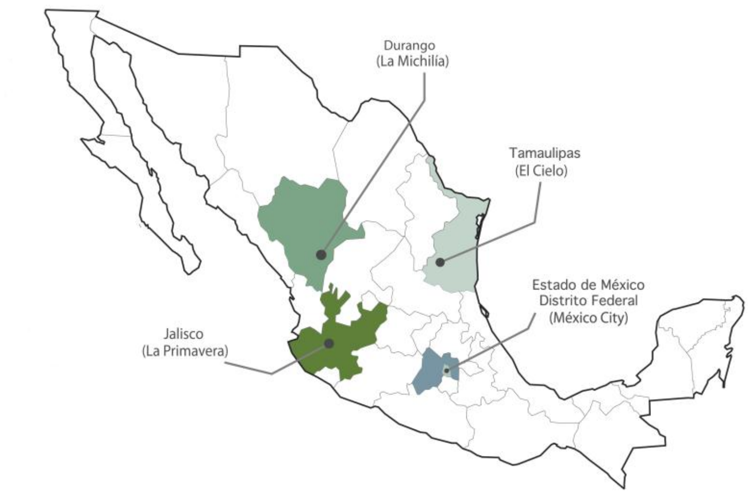
[21] All monetary figures in this Chapter are in US dollars ($USD), exchange rate used $MXP 13 per USD.

7.4.2. Sample

Respondents with a comparable socio-economic profile from the Mexican States of Durango, Jalisco, Tamaulipas and from México City were contacted online through an international market research company with a national database of more than 60,000 contacts; thus four samples were obtained (Figure 7.1). The target group consisted of mid-high and high-income adults with high school education or above. This group was not representative of the entire population in the regions, as would be expected from internet based studies (Thurston, 2006); however, comparability in terms of the environmental resource being valued and population characteristics, allowed isolation of the effect of location (Loomis and Rosenberg, 2006). The questionnaires were tested online and in person before application. The use of internet reduced the cost required for surveying, homogenized the application process and allowed the use of visual aids while covering a wide geographical range. Respondents with the desired profile were selected and invited by email to answer the survey. Participants completing the survey received an incentive for their participation from the market research firm (e.g. Diederich and Goeschl, 2011).

For the samples of Durango, Jalisco and Tamaulipas the experiment presented four choice sets where ‘local’ carbon offsets, located in the same State of residence, were in competition with ‘non-local’ options (outside the State of residence) and two choice sets where the options offered only non-local options. In the case of the sample from México City the six choice sets presented non-local options as the three locations proposed were outside the geopolitical boundaries of the metropolitan area (i.e. Federal District and State of México). The objective was to compare results from the three States with that from the México City sample, where no local offsetting option was available. Questionnaires were applied between November 2010 and March 2011 in 22 cities within the four regions in México (n=645). The size of each of the four samples was above that recommended for CE (Bennett and Adamowicz, 2001).

Figure 7.1. Study areas



Two types of analyses were made. For the econometric model once protests and the responses from those who found the CE confusing were identified, these were excluded from the dataset (Scarpa et al., 2009; Glenk and Colombo, 2011) and MNL and implicit prices were obtained to compare the geographical effect on environmental valuation. The Hausman-McFadden test was used to verify that the MNL complied with the model assumptions (McFadden, 1974; Hausman and McFadden, 1984; Maddala, 1983). Individual variables were adequately included in the models to overcome the model's restrictions (Bennett and Adamowicz, 2001). The equivalence of results across the samples was analysed by generating the 95% CI for the part-worths using the Krinsky and Robb method with 7,500 iterations and analyzing their statistical distributions following the complete combinatorial test (Krinsky and Robb, 1986; Poe et al., 2005). The second type of analysis consisted of comparing the characteristics of the four samples in terms of socio-economic and demographic profiles, attitudinal variables and preferences and previous environmental behavior; for these, the differences in the samples were analyzed through non-parametric tests and bivariate correlations.

7.5. Results

7.5.1. Characteristics of the Samples

The general characteristics of the samples in terms of socio-economic and demographic characteristics, attitudes and previous environmental behavior are presented in Table 7.1 and Table 7.2. Although the respondents' profile targeted a very specific group of the population, the four samples are not identical. All the respondents are middle aged, but the difference between México City and Jalisco is ten years. There was a larger percentage of females responding from México City. In terms of income, there is a lower income for Durango; however, the four samples correspond to persons who are in the higher 20% to 30% income groups according to national statistics (INEGI, 2011b). Durango is the smallest State in terms of population and contribution to the national gross domestic product, it also has the lowest internet penetration and this is likely to explain the lower income figures and number of responses. Perhaps the most marked difference regards the average distance from the city of residence to the closest local project location. The distribution of responses received within the States followed that of the population across local cities. The population of Jalisco is concentrated in the metropolitan area of Guadalajara, which is the capital of the state and is adjacent to La Primavera. In Durango State, Durango City is the capital and the largest city close to La Michilía; however, an important proportion of the population lives in the northeastern cities of Gomez Palacio and Ciudad Lerdo. Likewise in Tamaulipas although the capital Ciudad Victoria is closest to El Cielo, a large part of the population is distributed in the coastal region of Tampico-Madero-Altamira and the cities of Nuevo Laredo, Reynosa and Matamoros near the border (Figure 7.5 to Figure 7.7 in Appendices to this chapter). The Euclidean distances from each city to the reserves were computed from maps, and then the average distance to the local site was obtained for each sample. Euclidean distances have been used elsewhere to study spatial heterogeneity (e.g. Bateman et al., 2006; Campbell et al., 2008).

Table 7.2 shows that the respondents of Jalisco were more focused on location while answering the choice sets and had the highest percentage of previous visits to the local Reserve. Conversely the sample from México City had the largest share of respondents focused on cost and lowest number of visits and persons feeling responsible for their own emissions. For the combined sample 7.5% of the respondents had previously estimated their carbon footprint.

Table 7.1 Socio-economic and demographic characteristics (Percentages and Mean Values).

	Jalisco	Durango	Tamaulipas	México City	All
Age (years)	31.0***	31.5**	37.0*	41.5***	35.0***
Gender (% of Females)	36.7%**	35.0%**	41.4%	61.4%***	44.6%***
Civil Status (% Married)	41.8%*	49.0%	53.4%*	47.2%	47.8%
Respondent is Head of the Household (%)	47.5%	49.0%	52.4%	47.7%	49.2%
Size of Household (members)	3.86	3.99	3.97	4.09	3.98
Respondent has Children (%)	42.9%***	55.0%	57.6%*	55.1%	52.5%**
Education (Class)[a]	4.86	4.82	4.91	4.80	4.85
Income (Class) ($/month)[b]	1464***	1091***	1294***	1449***	1350***
Daily income ($/cap-day) [c]	14.42***	7.69***	9.83	12.82*	11.54***
Student (%)	24.3%	20.0%	15.2%**	21.6%	20.2%
Employee (%)	50.8%*	44.0%	44.5%	39.8%*	44.9%
Worker (belonging to workers' union) (%)	8.5%	16.0%**	11.5%	8.0%	10.4%
Domestic Occupation (%)	4.5%***	8.0%	15.2%***	10.8%	9.9%***
Entrepreneur (%)	23.7%	13.0%**	21.5%	25.6%	21.9%*
Economically Active (%)	75.1%*	58.0%**	67.0%	71.6%	69.1%**
Mean Distance to Closest Reserve (km)	29.5***	137.0	241.0	525.0***[d]	250.8***
n	177	100	191	177	645

Significance: *Significant at 90%; **Significant at 95%; ***Significant at 99%. Non-parametric tests using Mann-Whitney (U) to compare each sample to the other three, and the Kruskal-Wallis (H) for the four samples together (Column All)

[a] Income classes 1) below $150; 2) $151-$307; 3) $308-$615; 4) $616-$1153; 5) $1154-$2307 and 6) above $2307.

[b] Education classes: 1) Elementary School, 2)Jr. High School, 3)High School, 4) Technical Studies, 5) Undergraduate, 6) Postgraduate

[c]Considering the mid value of the income class, and the maximum value for income class 6.

[d.] Average distance considering the three sites.

Table 7.2 Preferences and previous environmental behaviour (Percentages).

	Jalisco	Durango	Tamaulipas	México City	All
Focus on Cost (%)	31.6%***	45.0%	34.0%**	53.4%***	40.4%***
Focus on Carbon (%)	22.6%***	35.0%	26.7%	39.2%***	30.3%***
Focus on Location (%)	45.8%***	20.0%**	39.3%***	7.4%***	29.3%***
Positive Probability Offsetting (%)	82.5%	84.0%	85.3%*	73.9%***	81.2%*
Responsibility for Own Emissions (RE) (%)	71.8%	72.0%	74.9%	65.9%*	71.1%
Previous Carbon Footprint (C) (%)	8.5%	6.0%	5.2%	9.7%	7.5%
Participated in Reforestation Campaigns (%)	55.5%	58.0%	53.1%	59.9%	56.4%
Visited La Michilía (%)	0.0%***	38.0%***	1.6%***	1.1%***	6.4%***
Visited La Primavera (%)	81.9%***	1.0%***	2.6%***	5.6%***	25.1%***
Visited El Cielo (%)	5.1%***	0.0%***	52.4%***	2.3%***	17.5%***
Visited at least one Reserve (%)	81.9%***	38.0%*	52.4%**	9.0%***	46.4%***
Donates to Environmental Associations (%)	19.8%	17.0%	21.5%	23.3%	20.8%
Previous Purchase Carbon Offsets (%)	-	-	1.0%	1.1%	0.6%
Protest (%)	9.0%	15.0%	10.5%	10.2%	10.7%
Found the questions Confusing (%)	9.0%	12.0%	8.9%	8.0%	9.2%
n	177	100	191	177	645

Significance: *Significant at 90%; **Significant at 95%; ***Significant at 99%. Non-parametric tests using Mann-Whitney (U) to compare each sample to the other three pooled, and the Kruskal-Wallis (H) for the four samples together (Column All)

7.5.2. Econometric Model

The MNL models for the four samples are presented in Table 7.3. When the MNL included only the experiment's attributes the IIA were violated; ASCs in combination with individual variables were included in the models shown to overcome this issue. No violations to the model's assumptions were found when a Hausman-McFadden test was applied by alternatively removing each project location and the opt out to check invariability of the parameters (Table 7.10 in Appendices); the models and most of the parameters are highly significant, with the expected signs and with statistical characteristics within the recommended ranges (Bennett and Adamowicz, 2001).

Table 7.3 MNL Models.

	Jalisco	Durango	Tamaulipas	México City
1.Intercept	-1.7630***	-2.0223***	-1.9900***	-2.2252***
2.Payment[a]	-0.0110***	-0.0086***	-0.0057***	-0.0070***
3.Carbon Offsets	0.1010***	0.0887***	0.0646***	0.0393***
4.La Michilía	0.6760**	3.5639***	0.6649**	2.5689***
5.La Primavera	4.3320***	0.9993**	0.5768**	2.4476***
6.El Cielo	-1.0420**	-0.5628	1.7425***	0.8708*
7.ASC1*F.Cost	0.9390***	-1.2569**	0.4228**	-0.2221
8.ASC1*F.Carbon	1.2860***	-1.1494**	0.4211**	-0.0884
9.ASC2*F.Cost	-2.6070***	0.1823	0.6399***	0.0914
10.ASC2*F.Carbon	-2.5210***	0.3771	0.5734***	0.0358
11.ASC3*F.Cost	0.2850	0.5683*	-1.5404***	-0.0924
12.ASC3*F.Carbon	1.3030***	1.1637***	-0.3079	0.6720*
13.ASC3* Payment/ Carbon	0.1370***	0.0896***	0.0919***	0.0852***
14.ASC2* Payment/ Carbon	0.0150*			
15.ASC1*Reforestation	-0.4790**			
16.ASC3*Children	-0.5970**			
17.ASC2*Head Household	-0.5420*			
18.ASC1*Payment/ Carbon		-0.0386***		
19.ASC1*Payment		0.0087**		
20.ASC1*Visit		0.5227*		
21.ASC3*Married		0.4548*		-0.5017***
22.Payment*Children			0.0024**	
23.ASC1*Head Household			0.3085*	
24.ASC1*Responsibility on Emissions			0.3932*	
25.ASC2*Female			0.2375	
26.ASC2*Children			-0.4645**	
27.ASC1*Female			0.3837**	0.3522*
28.ASC3*Visit				0.8780***
29.ASC3* Responsibility on Emissions				0.5158**
30.Female* Payment/ Carbon				-0.0115**
31.ASC2* Responsibility on Emissions				-0.2523
General Statistics				
Valid n	2,664	1,386	2,844	2,646
Model Fitting Information (Chi-Square)	839.4 (16)***	341.6 (16)***	642.01 (18)***	501.8 (18)***
Pseudo R-Squared	0.375	0.303	0.281	0.240

The variables "La Michilía", "La Primavera" and "El Cielo" capture the value of the group Focused on Location.
ASC1= Michilía, ASC2= La Primavera, ASC3= El Cielo.
Levels of significance: *Significant at 90%; **Significant at 95%; ***Significant at 99%.
[a]All monetary figures in US Dollars, exchange rate considered 1 USD = 13 Mexican Pesos.

The signs and magnitudes of the parameters in the models in Table 7.3 indicate the contribution of each variable relative to the individual's utility and to the probability of offsetting. Larger positive coefficients increase the probability of participation. Three groups of preference can be identified; these correspond to the respondents focused on cost, carbon or location. For the group focused on location, in the States of Durango, Jalisco and Tamaulipas, the preferred option was the local one; for the sample from México City the first option was La Michilía followed closely by La Primavera. The MNL models show that the respondents from Durango, Jalisco and Tamaulipas States focused on cost or carbon may give up a local project in favour of more cost efficient options. However, respondents would be more likely to purchase credits when local projects were offered, as the larger magnitude of the corresponding local projects indicates. If local projects produced offsets at a competitive cost, the groups of respondents with a stronger preference for cost or carbon could also choose a local project and maximize local co-benefits. The CE technique allows the estimation of implicit carbon prices and the utility derived from the project sites for the sub-groups focused on location (Table 7.4)

Table 7.4 Carbon prices and valuation of the project locations; mean (C.I. 95%)[a]

	Carbon Price ($/$tCO_{2eq}$)	La Michilía ($)	La Primavera ($)	El Cielo ($)	Extra Benefits Local Option (%)[b]	Distance (km)
Jalisco	9.18 (7.14, 12.05)	61.5 (18.5, 106.4)	393.8[c] (302.2, 535.0)	-94.7 (-167.5, -35.1)	540.8 (276.5, 1975.8)	29.5
Durango	10.26 (6.99, 16.54)	412.0[c] (232.3, 884.3)	115.5 (39.9, 242.8)	-65.1 (-215.7, 49.4)	256.6 (97.5, 965.9)	137
Tamaulipas	11.39 (7.62, 19.46)	117.3 (14.6, 254.9)	101.7 (12.0, 213.7)	307.3[c] (180.7, 586.5)	162.1 (33.0, 454.6)	241
México City	5.57[d] (2.90, 8.51)	364.4 (243.8, 571.7)	347.2 (218.2, 549.0)	123.5 (-4.2, 279.8)	5.0[e] (0.6, 62.9)	525[f]

[a] All monetary figures in US Dollars, exchange rate considered 1 USD = 13 Mexican Pesos
[b.] The confidence interval for the Extra Benefits Local Option (%) is generated using the exponential regression shown in all others are obtained using the Krinsky and Robb (1986) method with 7,500 iterations.
c. Higher valuation of the utility received from the local Reserves at 97% level or higher in comparison to the other project options for the groups focused on Location (Table 7.11 in Appendices).
d. Lower willingness to pay for carbon offsets when local projects are not presented at 97% level in comparison with the samples from the three States (Table 7.11 in Appendices).
[e.] Considering the two sites with the higher valuation (La Michilía and La Primavera).
[f.] Average distance to the three sites.

Table 7.4 shows that in the States where local offsetting options were available, respondents were willing to pay a higher price for carbon offsets than when no such options were offered. After applying statistical tests to the distribution of the carbon prices (Poe et al., 2005) the hypothesis of willingness to pay higher prices when local options are offered was accepted at 97% level or higher; the differences in carbon prices in the three samples where local options were offered cannot be accepted at meaningful significance levels and hence these are considered equivalent (Table 7.11 in Appendices). This indicates that when a local option was offered, respondents' decisions included factors other than only a cost-efficient removal of carbon from the atmosphere. For the sample from México City, where respondents were not offered a local option, the lower carbon price obtained suggests that respondents from this area searched for conventional cost-efficient options. When respondents from México City were asked to suggest alternative project locations 88.2% of the respondents to this question (n=34) proposed areas close to the city; 73.5% asked for areas which are very close to the city (Ajusco Mountain or La Marquesa Forest), while another 14.7% suggested the Monarch Biosphere Reserve, an iconic and well-known site which is home to the charismatic migrating butterflies. These areas are all within 25 and 130 km of México City.

7.5.3. Local Co-benefits

Respondents were asked why they preferred a local option (Table 7.5). Responses indicate that it was the proximity to the site and the access to co-benefits that are valued by the respondents, in addition to climate stabilization.

The co-benefit most commonly cited by respondents in Guadalajara in Jalisco (where on average the distance of the proposed project area to the participants' residence area is lowest) was related to local air quality. Respondents from this area frequently identified La Primavera as the "lungs of the city". Literature on the positive effects of urban and peri-urban forests on air quality is extensive; benefits include the absorption of pollutants (e.g. ozone, nitrogen and sulfur oxides), interception of particulate matter, oxygen production and increase in humidity and shade resulting in lower temperatures (McPherson et al., 2006). Additionally forest fires affect air quality (Carvalho et al., 2011), thus projects enhancing and protecting forests close to urban areas might help to reduce the occurrence of fires and the associated costs. These benefits are site specific; however, positive effects on air quality have been detected in peri-urban forests as far as 60 km away from the center of urban areas (Baumgardner et al., 2012).

Despite the fact that the corresponding local reserves in Durango and Tamaulipas are more distant from the respondents' residences than in Jalisco, the carbon price is significantly higher than in México City: the reasons cited for local projects in these states shifted from 'I live close to the area' to 'it is in my State/region' (Table 7.5). This shows the effect of the geopolitical thresholds and cultural identification in local valuation (Morrison and Bennett, 2004; Brouwer et al., 2010; Johnston and Duke, 2009). These results are congruent with other valuation studies: higher carbon prices for carbon sequestration in local projects resemble the higher valuation of water quality improvements in local catchments (Morrison and Bennett, 2004; Brouwer et al., 2010) and the valuation of local health co-benefits of climate policy (Longo et al., 2012).

Table 7.5 Reasons for local projects (open question).

	México City[a]	Jalisco	Durango	Tamaulipas
a. I live close to the area.	27.3%	26.7%	7.9%	5.7%
b. It is in my State/region.	1.6%	4.3%	14.3%	15.6%
c. To access local co-benefits	22.0%	15.7%	14.3%	20.6%
Local Air Quality	*75.9%*	*90.0%*	*44.5%*	*6.9%*
Landscape/Aesthethics	*7.4%*	*2.5%*	*11.1%*	*44.8%*
Water Services	*5.6%*	-	*22.2%*	-
Wildlife	*1.9%*	*2.5%*	*11.1%*	*24.1%*
Recreation/Tourism	*3.7%*	-	*11.1%*	*17.2%*
Local Public Health	*3.7%*	*2.5%*	-	*3.5%*
Economic Development	*1.8%*	*2.5%*	-	*3.5%*
Sub count of co-benefits identified	*54*	*40*	*9*	*29*
d. To protect that specific forest area.	21.2%	18.0%	17.5%	19.9%
e. To cooperate in improving the local environment.	22.0%	25.9%	34.9%	29.1%
f. For future generations (children)/general well-being.	4.5%	7.1%	11.1%	7.8%
g. Other.	1.2%	2.4%	-	1.4%
n (mentions)	245	255	63	141

[a.] For this question people from México City was asked to consider the development of a project in the Ajusco Mountain; the option of considering a project the Ajusco Mountain was presented after the respondents were asked to indicate an alternative project location.

7.5.4. Preferences and Profiles

Since the selection of cost, carbon or location as preferred attribute when answering the choice sets is associated to a differenced environmental valuation, the profiles of these three groups were analyzed in more detail (Table 7.6 to Table 7.8).

Table 7.6 and Table 7.7 show the mean values and bivariate correlation between the selection of cost, carbon or location as preferred attribute and individual characteristics. The tables show that when the proposed project location is closer to the city of residence of the respondent there would be a higher focus on location; they would have a better knowledge of the site given the higher familiarity with the site. Conversely when the projects are more distant there will be a higher correlation with focus on cost especially if the sense of responsibility for personal emissions is not stated; those who have estimated their carbon footprint would focus on carbon. The correlations in Table 7.6 show that those participants who had visited one of the reserves, felt responsible for personal emission and had previously estimated their carbon footprints correlated positively with the selection of location as preferred attribute. The choices made by

Table 7.6 Significant bi-variate correlations and cross-tabs between primary interest factors and individual characteristics.

	Focus on Cost	Focus on Carbon	Focus on Location
Age (years)	0.059	-0.096**	0.034
Civil Status (% Married)	0.028	-0.048	0.019
Head Household (Dummy)	0.065*	-0.095**	0.026
Respondent has Children (Dummy)	0.062	-0.098**	0.032
Income (Class)	-0.038	-0.025	0.067*
Student (Dummy)	-0.039	0.070*	-0.029
Entrepreneur (Dummy)	-0.031	-0.062	0.096**
Economically Active (Dummy)	-0.016	-0.074*	0.091**
Positive Probability Offsetting (Dummy)	-0.292***	0.135***	0.178***
Previous Visit (Dummy) (n=299)	-0.171***	-0.145***	0.331***
Carbon Footprint (C) (Dummy) (n=48)	-0.029	0.083**	-0.053
Resp. Emissions (RE) (Dummy) (n=459)	-0.207***	0.128***	0.094**
C and RE (Dummy) (n=32)	-0.087**	0.114***	-0.022
C and Previous Visit (Dummy) (n=23)	-0.022	-0.017	0.042
RE and Previous Visit (Dummy) (n=213)	-0.230***	-0.060	0.308***
C and RE and Previous Visit (Dummy) (n=15)	-0.064*	-0.012	0.081**
Protest (Dummy)[a]	0.358***	-0.217***	-0.168***
Found the survey confusing (%)	0.034	-0.045	0.008
Aggregate Carbon in Choices (%)[b]	-0.490**	0.520***	0.003
Aggregate Payment in Choices (%)[b]	-0.532**	0.492**	0.077*
Total Local Options in Choices (Choices)[c]	-0.445**	-0.015	0.495**
Average Carbon Price[d]	-0.173**	-0.103*	0.280***
Distance to Local Reserve	0.150***	0.119***	-0.282***
n	261	195	189

Significance: *Significant at 90%; **Significant at 95%; ***Significant at 99%. The contingency coefficient was used to compare nominal variables and Spearman bivariate correlations, following a Chi squared test.
[a]Protests were also correlated with those who did not considered these schemes as a good idea and those who found the questions confusing; [b]Value obtained by the summation of the offsets or payment in the six choice sets divided by the maximum possible value according to the version of the questionnaire; [c]Value obtained by the summation of the times that the closest (local) option was chosen in the six choice sets (max. 4); [d]Value obtained by the division of the summation of the payment by the summation of the offsets according to the choices in the six sets.

Table 7.7 Analysis of basic preferences as independent subgroups (percentages and means).

	Focus on Cost	Focus on Carbon	Focus on Location
Distance to Closest Reserve[a]	291.7*** (327.0)	288.8*** (319.0)	145.9*** (68.0)
Income ($/month)	1321	1328	1413*
Income per capita ($/cap-day)	13.57	13.69	14.19
Education (Class)	4.83	4.85	4.89
Age (yr)	36.9	34.4**	36.6
Female (%)	43.5%	48.7%	41.8%
Married (%)	49.6%	44.1%	49.2%
Respondent is Head of the Household (%)	53.1%*	42.1%**	51.3%
Respondent has Children (%)	56.2%	45.1%**	55.0%
Previous Carbon Footprint (C)	6.5%	10.8%**	5.3%
Responsible for own Emissions (RE)	59.6%***	80.0%***	77.8%**
Visited at least one Reserve (%)	36.2%***	35.4%***	72.0%***
Student (%)	18.1%	24.6%*	18.5%
Employee (%)	43.8%	43.1%	48.1%
Worker (belonging to workers' union) (%)	13.1%*	9.7%	7.4%
Domestic Work (%)	9.2%	12.3%	8.5%
Entrepreneur (%)	20.4%	17.9%	28.0%**
The respondent is economically active (%)	73.1%	68.7%**	79.9%***
Protest (%)	24.2%**	0.5%**	2.6%**
Aggregate Carbon in Choices (%)	37.6%***	78.6%***	58.0%
Aggregate Payment in Choices (%)	35.4%***	76.7%***	61.9%**
Times Local Option was chosen (Choice Sets)	1.36***	2.09	3.13***
Average Carbon Price[b]	8.61***	9.24*	10.70***
n	261	195	189

Significance: *Significant at 90%; **Significant at 95%; ***Significant at 99%. Non-parametric tests using Mann-Whitney (U) to compare each subgroup to the other two.
[a]The value in parenthesis shows the median.
[b]Value obtained by the division of the summation of the payment by the summation of the offsets according to the choices in the six sets

each participant when answering the choice sets were analyzed to get the aggregated values of carbon, costs and local choices as an alternative way to analyze the differences in these three groups. This analysis confirms the results derived from the MNL models. The group focused on cost correlates with the selection of choices offering less offsets and lower payments, conversely to those focused on carbon. The group focused on location is correlated with the selection of the local options and higher carbon prices; those focused on cost or carbon would give up local projects. Table 7.6 and Table 7.7 show that considering personal emissions as responsibility, the knowledge of personal carbon footprint and previous visits to the reserve are important factors related to the preferences for cost, carbon and location. Table 7.8 shows a detailed analysis of the participant in CE when these factors are used to group the respondents.

Table 7.8 Analysis of selected variables as independent subgroups (percentages and means).

	Responsibility on Emissions		Previous Carbon Footprint		Previous Visit	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Distance to Closest Reserve (km)[a]	238.2 (181.0)	272.3 (184.0)	247.0 (128.5)	247.7 (181.0)	120.6*** (51.0)	357.5 (462.0)
Income ($/household-month)	1359	1330	1617***	1327	1450***	1261
Income per capita ($/cap-day)	11.54	9.83	12.82	11.54	12.82***	9.83
Education (Class)	4.88	4.78	5.08	4.83	4.92	4.78
Age (yr)	35.0	35.0	30.5*	35.0	35.0*	36.0
Female (%)	47.6%**	37.1%	43.8%	44.6%	38.1%***	50.0%
Married (%)	46.9%	50.0%	22.9%***	49.7%	46.8%	48.6%
Respondent is Head of the Household (%)	47.4%	53.8%	45.8%	49.4%	50.5%	48.0%
Respondent has Children (%)	51.5%	54.8%	33.3%***	53.9%	51.5%	53.2%
Previous Carbon Footprint (C)	7.0%	8.6%	-	-	7.7%	7.2%
Responsible for own Emissions (RE)	-	-	66.7%	71.4%	71.2%	70.8%
Visited at least one Reserve (%)	46.5%	46.2%	47.9%	46.2%	-	-
Student (%)	20.1%	20.4%	31.3%**	19.3%	20.1%	20.2%
Employee (%)	45.4%	43.5%	29.2%**	46.1%	47.5%	42.5%
Employee (belonging to workers' union) (%)	10.0%	11.3%	8.3%	10.6%	10.4%	10.4%
Domestic Work (%)	9.4%	11.3%	8.3%	10.1%	7.4%**	12.1%
Entrepreneur (%)	22.7%	19.9%	25.0%	21.6%	25.1%*	19.1%
The respondent is economically active (%)	75.1%	70.4%	60.4%	74.7%	78.6%**	69.4%
Protest (%)	4.1%***	26.9%	20.8%**	9.9%	9.0%	12.2%
Protest, sub-sample with previous knowledge of carbon footprint corrected by RE (%)	*3.1%*** (n=32)*	*56.3% (n=16)*	-	-	-	-
Found the survey confusing (%)	8.1%	11.8%	9.9%	9.2%	10.0%	8.4%
Focus on Cost (%)	33.8%***	56.5%	35.4%	40.8%	31.4%***	48.1%
Focus on Carbon (%)	34.1%***	21.0%	43.8%**	29.2%	23.1%***	36.5%
Focus on Location (%)	32.1%**	22.6%	20.8%	30.0%	45.5%***	15.4%
Total Local Options in Choices (Choice Sets)	2.25***	1.72	1.65**	2.14	2.44***	1.80
Aggregate Payment in Choices ($)	445.5***	306.2	390.0	406.6	409.1	402.1
Aggregate Carbon in Choices (tCO_{2eq})	47.9***	32.7	42.9	43.6	43.7	43.4
n	458	187	48	597	299	346

Significance: *Significant at 90%; **Significant at 95%; ***Significant at 99%. Non-parametric tests using Mann-Whitnney (U) to compare each subgroup for each variable.
[a]The value in parenthesis shows the median.

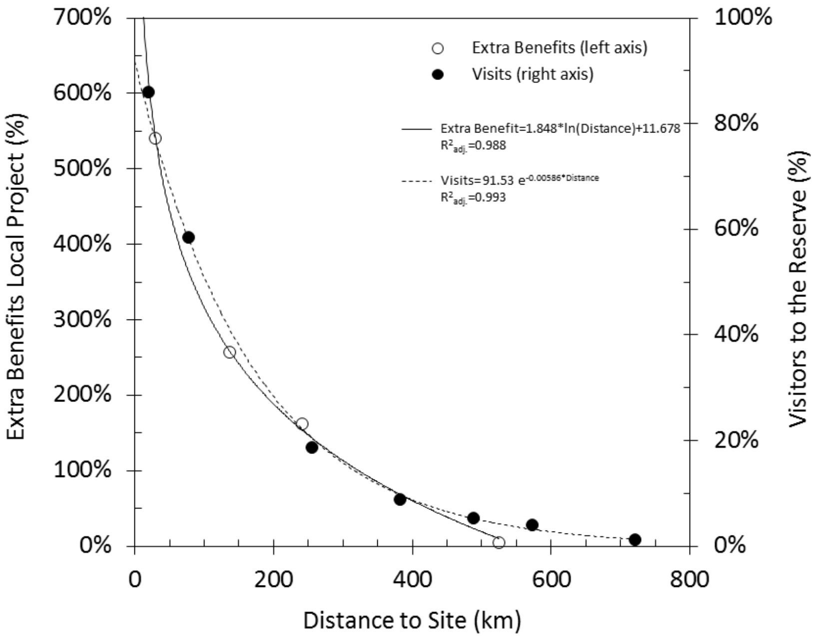
The sense of responsibility, knowledge of personal carbon footprint and previous visits to the reserves are used to characterize the differences in the profiles of the participants in the CE. Females tend to feel more responsible for personal emissions; the assumption of responsibility is not correlated to income, knowledge of emissions or previous visits, and it is associated to lower protests and choices of higher payments, offsets and local options in the CE. The profile of those with previous knowledge of their carbon footprint includes a larger proportion of younger citizens, who are students who come from households with higher total income; previous knowledge of emissions is correlated with fewer choices of local projects; however, the purchase of more offsets is associated to higher sense of responsibility and not to previous knowledge of carbon emission or previous visits to the sites. The knowledge of carbon footprint appears to be correlated with protests, however, when this is corrected for the sense of responsibility it can be seen that protests of those with previous knowledge of personal emissions arise prominently when participants do not feel responsible for them. The profile of those who had previously visited the reserves corresponds to those living closer to them and who in general are economically better-off (i.e. in terms of income, entrepreneurship and economic activity); there is a lower percentage of females in this group due to the higher proportion of females in the sample from México City (Table 7.1). Previous visits are correlated with more choices for local options in the choice sets, but there are no changes in terms of aggregated payment and offsets selected.

The analysis derived from Table 7.6 to Table 7.8 indicates that if economic pressures are high and potential offset purchasers do not feel responsible for personal emissions, decisions may be based on cost, or respondents may declare themselves unable/unwilling to pay (protests). If citizens feel personally responsible for their emissions they may however, not focus on cost; instead, location would play an important role, particularly as proximity and possibility of visiting the project increases. These determinants of environmental valuation have been commonly reported in the literature (Johnson and Nemet, 2010; Bamberg and Möser, 2007) (e.g. environmental responsibility (Brouwer et al., 2008), proximity (Garrod et al., 2012), familiarity with offsetting schemes (Ziegler et al., 2012), income and trust in the scheme (Adaman et al., 2011)) and can be used to design domestic carbon markets targeting local demand. However, the preference for cost, carbon or location and the sense of responsibility over personal emissions are unobservable characteristics. Strategies to increase public awareness in climate change mitigation can include dissemination of carbon footprint based tools and promotion of controlled visits to forested areas; and dissemination of information on the importance of environmental services. However, if the sense of responsibility is not present this may not be enough to engage citizens into participation.

7.5.5. Distance Decay Functions

In order to assess the distance decay of local direct co-benefits, the valuation for each site in Table 7.4 was considered along with the reported information on visits to the reserves. Responses on visits were clustered into distance groups. The values for each project location in Table 7.4 are used as proxies of local benefits and correspond to the utility received from each site by those who had a stronger preference for project location in each sample during the experiment (i.e. those who answered that the most important factor when answering the choice sets was project location). The utility received from the most preferred site (local option) in comparison to the second best option is used as a proxy of the extra benefits of local projects for this group of respondents. Both the extra benefits of local projects and the visits to the sites were plotted against the Euclidean distance to the reserves Figure 7.2 shows that the direct extra benefits of a local project decrease logarithmically; for the information on visits the best results are obtained when an exponential function is used. These figures are in agreement with other distance decay functions reported (e.g. Bateman et al., 2006). Each point in the curve for extra benefits refers to each of the samples (i.e. Jalisco, Durango, Tamaulipas and México City by descending average distance to site). As shown above the preference for project location is correlated with previous visits, which is facilitated if forests are proximate. The preference for location in the CE is also correlated with the selection of options with relatively higher carbon prices that will lead to maintenance of local co-benefits. Thus it could be expected that the distance decay patterns of the valuation of local options by those focused on location would be similar to the information on previous visits. The curves imply that higher valuation and potential visits are expected in areas closer to the cities up to a distance of 150 to 200 km. The distance to the areas suggested as alternative sites by the respondents from México City are also within this range. Other studies have also reported spatial heterogeneity closer to urban populations in the valuation of recreation and other forests services (e.g. Abildtrup et al., 2011; Garrod et al., 2012). In agreement with research on the valuation of water quality (Brouwer et al., 2010) and biodiversity services (Garrod et al., 2012), results indicate that citizens value climate mitigation in forests in the three sites proposed. However, the direct co-benefits received from a forest increase rapidly when it is closer to the persons valuing it, increasing the chance for participation in activities to conserve them and mitigate climate change (Figure 7.2).

Figure 7.2 Local co-benefits for the group focused on location and previous visits (all participants), from local projects as a function of average distance from the respondent's city of residence.



7.5.6. Implications for Domestic Forest Carbon Markets

Results of this experiment show that when potential carbon offset buyers are distant from the project area, decisions tend to be dominated by cost-efficiency as expected by market theory. However, given the possibility of buying local offsets, buyers may not only want to reduce costs, but also to maximize local co-benefits (e.g. environmental services, regional identification). Co-benefits of proximate projects can outweigh climate mitigation benefits of more distant projects for a significant share of the population. Results from the individual's stated choices agree with the analysis of climate policy made at the international level: the trade-offs between non-local cost-efficient options and local options which also generate co-benefits determines the valuation and demand of offsets in market-based mechanisms (Pearce, 2000). It is obvious that if only 'distant' projects are generated and registered in the carbon markets, offset buyers would not have to make trade-offs between local and non-local mitigation actions. However, given the possibility of developing local projects as part of new domestic mechanisms it is expected that ceteris paribus these local options will be preferred by citizens. As national policies and domestic carbon markets mature they will become new catalysts for the demand for forest carbon offsets which can be increased further if projects are developed closer to the offset buyers.

Nevertheless, implementation costs and the landowners' willingness to participate in these schemes also need to be considered when analyzing the potential of projects in market-based mechanisms since higher land opportunity costs are expected in areas closer to the cities. However, experience from the national PES program in México shows that landowners and communities are willing to participate with payments starting at $23.1 per ha per year (Muñoz Piña et al., 2008), even when some of them are located in areas close to large cities (e.g. La Primavera). Moreover, governments can decide to shape domestic climate policy and the institutional framework of local markets in such a way that it maximizes local social welfare; thus forest conservation, expansion and enhancement projects can be promoted in highly valued areas. This can be done, for instance, through reduction of transaction costs for the implementation of projects in valued regions (e.g. generation of regional baselines, identification of eligible areas for carbon sequestration projects) or through the creation of specific sub-national REDD+ projects targeting activities in areas benefiting more people (i.e. landowners and communities owning the forests but also the citizens living close by the forested areas). However, clear and effective land use change policies, regulations and controls, are necessary preconditions, otherwise incentive-based mechanisms will not be able to compete with land opportunity costs; this is not a minor consideration since market-based mechanisms may not be the best policy option to ensure the provision of forest services in the presence of multiple public and market failures (Engel et al., 2008).

The values obtained here show the differences in environmental valuation within the limits imposed by the CE; potential buyers may pay even more than the prices obtained here depending on the outcomes of specific negotiations with project developers, as experience from ongoing projects to date indicates. The average carbon price for REDD+/avoided conversion-based projects and afforestation/reforestation projects in 2010 was \$5 and \$9/tCO_{2eq} respectively (Peters-Stanley et al., 2011). However, maximum prices for REDD+ projects may be around \$25/tCO_{2eq}, while for improved forest management the maximum was above \$136/tCO_{2eq} (Peters-Stanley et al., 2011). The amount of offsets and costs chosen in the experiment reflect the existing conditions of the voluntary market in México; results indicate that although these practices are not yet widespread, citizens would participate and buy offsets at current prices.

It is important to point out that valuation of forest climate services in markets faces a structural obstacle since they are considered temporary, while credits from other projects are regarded as permanent (e.g. energy efficiency, renewable energy). The argument for the permanence of non-forestry projects is flawed as there is no guarantee that fossil fuels associated with the 'permanent' emissions saved one year will not be extracted and burned later while it is still economically viable (Skutsch and Trines, 2010). Clean technology reduces the extraction rate and use of fossil fuels generating climate benefits just as forestry-based practices (e.g. REDD+) may reduce emissions from the forest sector (Skutsch and de Jong, 2010). Moreover, any reemission of forest carbon can be offset by reforestation without net additions to atmospheric carbon stocks while carbon from fossil fuels represents net increases to this (Skutsch and de Jong, 2010). If forest carbon credits are homologized with other types of credits this might increase their valuation in the markets. Another alternative for this is the adoption of specific targets for emission reductions and/or for carbon enhancement/ sequestration in the forest sector (setting a minimum 'use' rather than a maximum cap as it is defined now). However, if discussed under the UNFCCC, these changes are likely to follow a long and difficult process of negotiation. The valorization of forest climate services can be made explicit more rapidly if these changes are considered in domestic policies and markets.

7.6. Conclusions

The development of domestic carbon markets targeting local demand can help to increase the valuation and demand for forest climatic services during the period while the future of global markets remains uncertain. Forestry climate mitigation actions developed close to urban areas have the potential to create large co-benefits and increase local welfare. These public preferences can be helpful in designing climate policies aimed at maximizing local welfare and will also increase their public acceptance. Domestic policies can realize the value of forest carbon services more rapidly since they do not require negotiation and adoption of international legally binding emissions reduction targets; however, domestic policies do need to generate a sense of responsibility for emissions among local actors and also the formulation of appropriate local institutional frameworks (e.g. land use regulations). A critical step to empower citizens and engage them in climate change mitigation efforts is the creation of effective and accessible options enabling local action.

7.7. Corollary: Required Demand of Forest Carbon Services for a Local Market in La Primavera-Guadalajara

In this section the potential for a local market is assessed from the demand side. For this the minimum number of local offset buyers in the metropolitan area of Guadalajara (MAG) willing to neutralise their carbon emissions locally in La Primavera is estimated considering current levels of GHG emissions (i.e. citizens or companies). Forest carbon services are estimated setting the REL at 1.84% (Chapter 4). Potential carbon services would be 204.7 $ktCO_{2eq}$/yr (164.4 – 246.0 $ktCO_{2eq}$/yr). Estimates of personal emissions are based on the average per capita emissions in México, 6.8 tCO_{2eq}/yr (SEMARNAT, 2009); the population in the MAG in 2010 was 4.4 million (INEGI, 2011a). However, emissions and consumption are not homogenous, they depend on the affluence or lifestyle (e.g. Feng et al., 2009), reflected in different consumption patterns, which are restricted by income. Following Balderas Torres et al., (2010b), when differences in income/expenditure are considered, emissions of the 20% of the population with highest income become 19.04 tCO_{2eq}/hab-yr (See Section 7.7.1 below). This socio-economic profile coincides with that of participants in the choice experiments. Additionally the required participation of the private sector is considered using levels of emissions reported in voluntary corporate inventories of GHG emissions in México (GEIMÉXICO, 2012). Most of the corporations reporting their emissions are big companies; according to the official statistics in the MAG there are 4,136 companies out of which 359 are big (more than 250 employees) (SIEM, 2012). The reference level of emissions for big companies is set at 20,000 tCO_{2eq}/yr (See Section 7.7.2 below). Table 7.9 presents the required participation to completely value forest carbon services in La Primavera; the required expenditures per capita and per firm are estimated at a carbon price of $10/$tCO_{2eq}$.

Table 7.9 Required participation and expenditure within the population and private sector in the MAG to finance climate change mitigation in La Primavera, Jalisco (Mean, Min. and Max. values in reference to potential production of forest carbon services).

Potential Buyers	Mean (Min.-Max)	Participation Required	Expenditure ($/hab, $/firm) @ $10/$tCO_{2eq}$)
Citizens (national per capita emissions)	30,105 (24,181 – 36,170)	0.68% (0.55% - 0.82%)	$68
Citizens (20% higher income group)	10,750 (8,636 – 12,918)	0.24% (0.20% - 0.29%)* 1.22% (0.98% - 1.47%)**	$190
Big Companies	10 (8 - 12)	2.85% (2.29% - 3.43%)	$200,000

*In relation to all the population of the MAG; ** In relation with the 20% of the population with highest income.

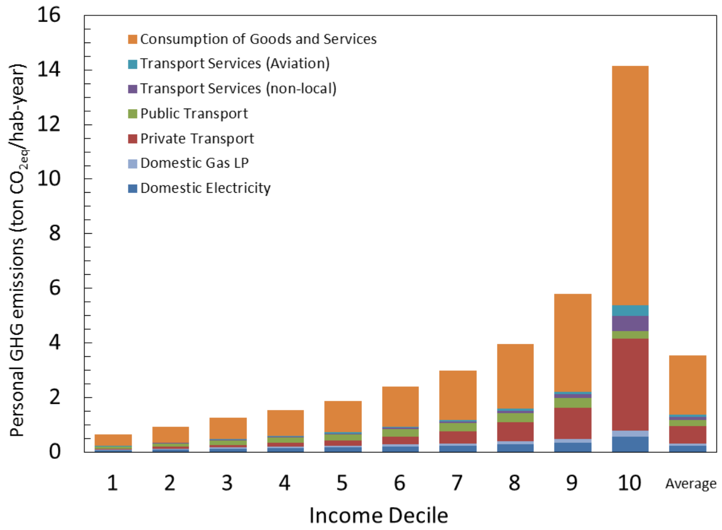
Table 7.9 shows that a relatively low level of participation is required to finance climate change mitigation activities in La Primavera. The minimum level considering civil participation demand would be of 1% or less; responses to the potential participation presented in this chapter indicate that around 80% of the respondents to the survey would participate if the projects became operational (similar results were reported in Chapter 6). In the private sector this would range from 2% to 3% in terms of local big companies, which is only 0.25% of total private organizations in the city. While the potential among the private sector needs to be evaluated in detail, the higher valuation of local mitigation among entrepreneurs in the choice experiment could indicate positive prospects. Furthermore companies oriented to local consumers could capitalize local public preferences by participating in a local market. The required payments from citizens at this price are similar to those presented to the participants in the choice experiments. The expenditure represents a payment from \$0.18 to \$0.52 per day per person to neutralise 100% of yearly carbon emissions. If carbon prices negotiated are different expenditures can be easily adjusted. The low levels of participation required to fully finance the potential forest carbon services in La Primavera indicate the low relatively capacity of La Primavera to offset the large GHG emissions from the MAG. In this context, it is possible to identify the scale of participation required to channel resources also to the currently unprotected wildlife corridors. According to ecological studies, the minimum range area for a population of pumas would be between 120,000 to 200,000 ha (Beier, 1993). Using these values as a reference and assuming a similar carbon potential, the required participation to finance these activities for a larger area would be 4 to 7 times those presented in Table 7.9.

Figure 7.3. View from La Primavera Biosphere Reserve towards the Tequila volcano, one of the wildlife corridors in 2009 (Picture taken by Arturo Balderas Torres).

7.7.1. Personal Emissions

The statistics of income and expenditure in Mexican households (INEGI, 2007a) can be used in combination with the national GHG inventory (SEMARNAT, 2009) to determine how emissions would be distributed among different groups of income according to the expenditure observed in different sectors of the economy (Balderas Torres et al., 2010b). Figure 7.4 shows the distribution of emission across income groups considering energy, transport and general consumption of goods and services. This scope accounts only for 53% of national emissions; the remaining 47% corresponds to GHG emissions from waste management, agriculture, fugitive emissions, other consumption and LULUCF. Emissions from the sectors considered account for an average of 3.56 tCO_{2eq}/hab-yr. However, when patterns of expenditure/consumption are considered, per capita emissions change drastically. In the estimation of the emissions per capita for the 20% of the population with highest income (and higher consumption), it is assumed that the remaining 47% of the emissions not included in the scope presented Figure 7.4 are also driven by consumption and thus by income. Thus the emissions of this group would be 2.8 times the average emissions, 19.04 tCO_{2eq}/hab-yr. Differenced income/consumption and emissions/energy-consumption patterns have also been found and reported in other countries (e.g. in US, Markham, 2009; China, Feng et al., 2009; and India, Ananthapadmanabhan et al., 2007).

Figure 7.4 Emissions profile from consumption depending on income/expenditure levels



7.7.2. Corporate Emissions

The emissions of the private sector are obtained from voluntary GHG emissions reports. In México there is a voluntary initiative by which private organizations can report their GHG inventories; this is the GHG Program México (GEIMÉXICO, 2012). Excluding the 10 largest companies reporting their GHG emissions in 2010, which include nationwide emissions from the oil, cement, retail and other companies (e.g. PEMEX, CEMEX, WALMART), the average yearly GHG emissions per company were 116,300 tCO_{2eq} (with a median of 18,300 tCO_{2eq}/yr, n=54). Additionally the GHG inventories in 2007 from two big companies located in Jalisco are considered as reference to identify the emissions and potential carbon demand: a tequila factory located in the municipality of Tequila (close to the MAG) reported emissions for 23,503 tCO_{2eq}/yr and a manufacture factory from the automobile sector located in El Salto in the MAG reported 18,804 tCO_{2eq}/yr (GEIMÉXICO, 2012). Considering the median as described above and the two local examples the level is set at 20,000 tCO_{2eq}/yr.

7.8. Appendices

Table 7.10 Results of the Hausman-McFadden test

Sample	Option Removed			
	La Michilia	La Primavera	El Cielo	Opt Out
Jalisco	13.4 (13), χ^2=22.3	5.0 (12), χ^2=21.0	2.7 (12), χ^2=21.0	0.0 (16), χ^2=26.3
Durango	1.6 (11), χ^2=19.6	18.4 (14), χ^2=23.6	0.3 (12), χ^2=21.0	0.4 (16), χ^2=26.3
Tamaulipas	15.9 (14), χ^2=23.6	12.2 (15), χ^2=24.9	6.1 (13), χ^2=22.3	0.0 (18), χ^2=27.6
México City	20.0 (15), χ^2=24.9	11.5(15), χ^2=24.9	1.0 (13), χ^2=22.3	0.5 (18), χ^2=27.6

The number in parenthesis shows the degrees of freedom, χ^2 shows the critical value at 95% level.

Table 7.11 Results of the complete combinatorial test applied to the carbon prices and valuation of each project area presented in Table 7.4.

Hypothesis	Complete Combinatorial Test (p-value) (Poe et al., 2005)	Hypothesis Accepted at X% Level	Comment
Higher Carbon Price in Jalisco than in México City	0.025	97.4%	Higher Carbon Price when local projects were offered
Higher Carbon Price in Durango than in México City	0.020	98.0%	
Higher Carbon Price in Tamaulipas than in México City	0.009	99.1%	
Higher Carbon Price in Tamaulipas than in Durango	0.375	Rejected	Equivalent carbon prices among three samples with local options
Higher Carbon Price in Durango than in Jalisco	0.202	Rejected	
Higher Carbon Price in Tamaulipas than in Jalisco	0.327	Rejected	
Higher Utility from La Primavera than from La Michilia in Jalisco	0.000	>99.9%	
Higher Utility from La Primavera than from El Cielo in Jalisco	0.000	>99.9%	
Higher Utility from La Michilia than from El Cielo in Jalisco	0.000	>99.9%	
Higher Utility from La Michilia than from El Cielo in México City	0.011	98.8%	
Higher Utility from La Michilia than from La Primavera in México City	0.437	Rejected	
Higher Utility from La Primavera than from El Cielo in México City	0.017	98.3%	
Higher Utility from La Michilia than from La Primavera in Durango	0.005	99.5%	
Higher Utility from La Michilia than from El Cielo in Durango	0.000	>99.9%	
Higher Utility from La Primavera than from El Cielo in Durango	0.008	99.2%	
Higher Utility from La Michilia than from La Primavera in Tamaulipas	0.414	Rejected	
Higher Utility from El Cielo than from La Michilia in Tamaulipas	0.022	97.8%	
Higher Utility from El Cielo than from La Primavera in Tamaulipas	0.009	99.1%	

In Figure 7.5 to Figure 7.7, each circle represents one city or metropolitan area in each State; the relative size of the circles indicates the contribution to the sample from each city.

Figure 7.5 Jalisco

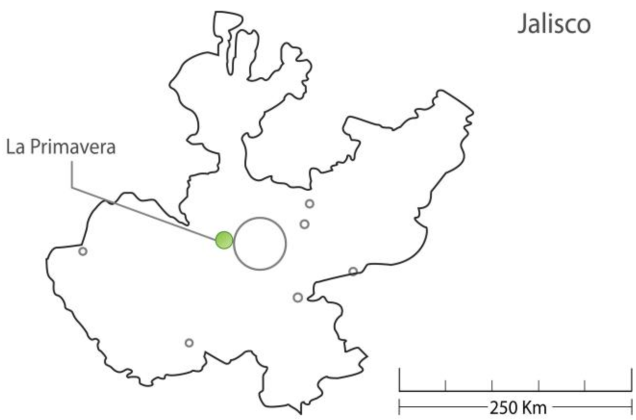


Figure 7.6 Durango

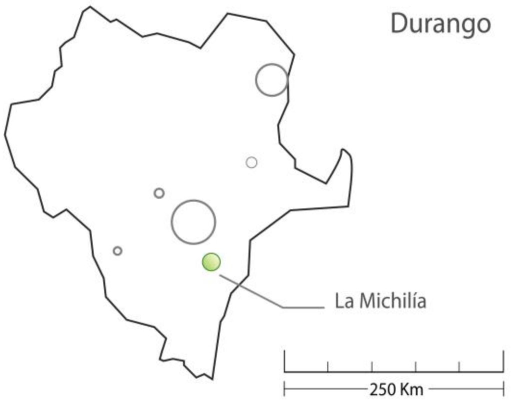
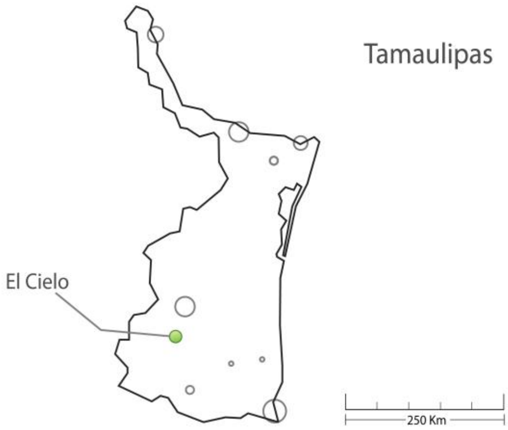


Figure 7.7 Tamaulipas



8. Payments for ecosystem services and rural development: landowners' preferences and potential participation in western México[22]

8.1. Abstract

Incentive-based mechanisms can contribute to rural development and deliver environmental services, but need to be attractive to landowners and communities to ensure their participation. Here we study the views of landowners and agrarian and rural communities (*ejidos*) from central Jalisco in México to identify characteristics that payment for environmental services (PES) programs conserving/enhancing forest cover could include in their design. A choice experiment was applied to 161 landowners and ejidatarios. Results show that importance and dependency on cash payments can decrease if interventions to promote local development are included. Responses indicate that communal forested areas in ejidos would be most likely to enroll into PES; in some cases grasslands could be afforested to make them eligible for participation in the future. Agroforestry practices providing other environmental services could be implemented (e.g. windbreaks). Potential enrolment is lower in agricultural and peri-urban areas due to higher opportunity costs. Higher payments favour enrolment but may compromise the program's efficiency since aggregated cash-flow over long periods can exceed the present value of land itself in some areas. Offering a mix of cash and non-cash benefits based on local developmental needs might be the best way to promote participation in PES.

8.2. Introduction

In recent years interest in improving our understanding of the institutional and economic arrangements needed to maintain the ecosystem services has increased considerably in the scientific literature (Balvanera and Cotler, 2007). These ecosystem or environmental services include regulation, habitat, production and information functions (de Groot, 1992; de Groot et al., 2002), can be present at local or transboundary scales (López-Hoffman et al., 2010), and include benefits such as protection of water catchments and biodiversity habitat, sites for recreation and climate change mitigation (Canadell and Raupach, 2008). However, many of these benefits are public goods, hence landowners and communities protecting the ecosystems providing them are often not compensated. In other words, there is a market failure as the value of the services are not recognized by the consumers and the so the producers may opt for land uses other than those that provide the services. As a result, environmental services and functions can be lost when they are not factored into landowners' land use decisions (e.g. Grieg-Gran et al., 2005, Pagiola et al., 2002). The aim of this chapter is to explore the potential participation of

[22] The material presented in this chapter has been submitted to be considered for publication as Balderas Torres, A., MacMillan, D.C., Skutsch, M., Lovett, J.C. Payments for ecosystem services and rural development: landowners' preferences and potential participation in western México; the Appendix and the Corollary to this Chapter were not included in the aforementioned submission.

landowners in incentive-based mechanisms for the conservation of forests using a region in western México as a case study.

Recent environmental policies have aimed to solve the problem of market failure by creating positive incentives for landowners through a number of approaches including market-based mechanisms and subsidies (e.g. Kinzig et al., 2011; Landell-Mills and Porras, 2002; Muradian et al., 2010). These policies seek to support practices that maintain and enhance provision of environmental services through payments to the service providers. Usually these payments are designed to match the opportunity costs of alternative land uses that imply reductions in the flow of environmental services (Pagiola and Platais, 2007). Programs of payments for environmental services (PES), carbon sequestration projects financed through carbon markets and policies to incentivize reductions in emissions from deforestation and forest degradation in developing countries (REDD+) are examples of these schemes. It is important to identify the context within which these policies are to be applied. Lack of property rights over land, incomplete information on management practices, benefits and costs, or lack of access to capital markets (e.g. credit) the appropriateness of a PES or incentive-based approach may be analyzed and considered in a policy mix (Engel et al., 2008).

Incentive-based schemes are often considered to have the potential to contribute to poverty alleviation and poverty prevention (Daw et al., 2011; Grieg-Gran et al., 2005; Landell-Mills and Porras, 2002; Muradian et al., 2010; Pagiola et al., 2002; Wunder, 2005). Contributions to poverty alleviation come from direct benefits derived from maintenance and access to the environmental services; and co-benefits associated with the projects such as cash-income and labour opportunities (Daw et al., 2011). This type of scheme may only succeed in the long term if the benefits generated are considered adequate by local communities and landowners (Engel et al., 2008; Grieg-Gran et al., 2005; Landell-Mills and Porras, 2002). Theoretical and empirical research has shown that rural landowner participation in incentive programs is influenced by different factors including the characteristics of the schemes, the characteristics and attitudes of the individuals and the activities developed on the land (e.g. Ma et al., 2012; Putten et al., 2011).

In addition to direct environmental services and direct payments, other benefits can also be considered in a broader developmental context in the valuation of ecosystem services. According to the livelihoods approach, the level and potential for development is related to the levels and changes in social, human, productive, financial and natural capitals (e.g. Carney, 1998). As described by Landell-Mills and Porras (2002) PES can have positive effects in the five dimensions of capital through enhancement of local environmental services which are enjoyed locally by the providers; by strengthening local institutions; building capacity and transferring specific know-how; by the creation of specific infrastructure associated with human and productive capital (e.g. tree nurseries, roads, health care centers, schools); and through cash payments and increased access to markets that increase financial capital. Yet most incentive programs offered as part of PES have focused primarily on financial compensation only, for example the Mexican PES program (Muñoz-Piña et al., 2008). In a review of 47 PES schemes for watershed services Brouwer et al., (2011) report that in around 70% of the cases analyzed the main mode of compensation was through cash payments. Low payments may represent small contributions to the landowner's total income and adoption of PES is likely to indicate the low opportunity costs of enrolling in the programs (e.g. PES contributed from 1% to 3% of yearly income to participants in Coatepec México) (Scullion et al., 2011).

It is possible to design programs to conserve environmental services based on the livelihoods approach. An example of such a program is Bolsa Floresta in the Brasilian Amazon (Viana, 2008). This program provides four types of support to participants engaging in forest conservation: a fixed monthly payment per household; community payments for income generation activities; community payments for the development of local infrastructure such as water sanitation, health or education centers or roads; and resources to strengthen local institutions and organizations (Newton et al., 2012; Viana, 2008). It is a governmentally mixed program in which international development agencies and locally based non-governmental organizations also participate (Newton et al., 2012).

In this chapter we explore the potential participation of landowners from the central region of the state of Jalisco, México, in a PES scheme aiming to conserve and enhance forest cover. We developed a choice experiment to elucidate the effect that cash payments, project duration and potential access to other co-benefits promoting local development as part of the project might have in potential participation. Based on participant responses we discuss the implications for PES design and the contribution to rural development and provision of environmental services. First we present background information about participation of landowners in incentive-based programs. Then we describe the methods used and study area, followed by the results and discussion. Finally, we present our conclusions.

8.3. Background

8.3.1. Forestry Incentive-based Programs and Landowner Participation

Concern over relative scarcity of natural services is leading to promotion of policies for the creation of incentives to conserve diminishing ecosystem functions (Kinzig et al., 2011; Kroeger and Casey, 2007). PES was initially defined by Wunder (2005) as a voluntary agreement between at least one buyer and one seller, based on provision of a specific environmental service. A more recent definition considers PES as the transference of resources among social actors, through markets, incentives or subsidies, to align the management of natural resources with a wider social interest (Muradian et al., 2010). Benefits for the providers participating in PES can include cash and in-kind payments, capacity building, income diversification, reliable and stable payments and improved organization (Grieg-Gran et al., 2005). As opposed to command and control policies, PES and market-based mechanisms generally rely on voluntary participation of landowners in environmental management, thus the incentives offered by these projects need to be of a type and level which attracts participation (Engel et al., 2008). Economic theory assumes that if landowners decide to participate in incentive-based programs, it is because the benefits received make them at least as well-off as they were without the program (Grieg-Gran et al., 2005).

Previous research indicates that there are a range of factors promoting or preventing participation of landowners in incentive-based schemes. Theoretical and empirical studies indicate a greater potential for participation when payments are higher (e.g. Dickinson et al., 2011; Lynch et al., 2002; Markowski-Lindsay et al., 2011; Putten et al., 2011). However, there may be landowners already interested in conservation who are willing to participate and for whom the flexibility of the scheme might be more important (e.g. Horne, 2004; Putten et al., 2011; Scullion et al., 2011; Stevens et al., 2002). In general, landowners prefer simpler projects without additionality requirements (Markowski-Lindsay et al., 2011), with lower compliance costs (Putten et al., 2011), not requiring specific management programs and not including penalties for non-compliance or early withdrawal (Dickinson et al., 2011, Markowski-Lindsay et al., 2011). Schemes offering upfront payments might be preferred (Putten et al., 2011) as they maximize net present value (Balderas Torres et al., 2010a). There is also a preference for shorter project lengths since this allows more management flexibility in the future, especially when inter-generational aspects are considered (Dickinson et al., 2011; Horne, 2004; Markowski-Lindsay et al., 2011; Putten et al., 2011; Stevens et al., 2002).

Participation in PES schemes has been linked with higher income, off-land income, youth and education level, low levels of household debt and more labour available in the family (Balderas Torres, 2007; Dickinson et al., 2011; Dupraz et al., 2003; Greiner et al., 2003; Lambert et al., 2007; Loftus and Kraft, 2003, Petrzelka et al., 2012; Putten et al., 2011). Positive participation has also been related to larger property size (Kilgore et al., 2008; Ma et al., 2012, Putten et al., 2011), to properties located closer to the household (Balderas Torres, 2007), and also previous knowledge of the program and positive attitudes towards the environment (Ma et al., 2012; Putten et al., 2011). Landowners may have different reasons for owning their land and they may be positive about pro-conservation incentive programs as long as these do not conflict with their core interests or business objectives (Church and Ravenscroft, 2008; MacMillan and Phillip, 2010). In areas with more pro-development land use regulations, relatively lower participation in incentive-based conservation programs is expected since more profitable activities would be considered by landowners (Markowski-Lindsay et al., 2011).

8.3.2. PES in México and Land Tenure

The federal Mexican government started the national PES program in 2003 to monetarily compensate landowners and communities for conserving forests (Muñoz-Piña et al., 2008; Rico Garcia-Amado et al., 2011). The payment level was estimated by the government according to a deforestation risk map and does not cover opportunity costs (Corbera et al., 2007; Rico Garcia-Amado et al., 2011). Incentives to landowners consist of yearly payments over five years; participation can be renewed depending on performance and the budget available. In addition to the federal program, other PES programs have been created including a number developed jointly with the private sector and others at the municipal and state levels. The payment levels range from $22.2 per hectare per year in the federal program to $111 for the Pro-Bosque program in the State of México (Estado de México, 2011; Muñoz-Piña et al., 2008; all monetary figures presented in this chapter are in US dollars, the exchange rate used is $13.50 Mexican pesos per dollar).

In México land tenure includes public, private and community or *ejido* property regimes. In the private property regime potential enrolment into PES or other conservation programs constitutes an individual decision. Under the ejido or community regimes, a group of individuals is given entitlement to an area of land by presidential decree. One part of this is divided into individual parcels, usually with potential for agricultural activities, so that each ejidatario decides how to use this for him/herself. Another part of the land becomes a common area and usually this has remained as forest. Decisions regarding the activities in common areas, such as enrollment into PES, are taken communally in the official ejido assemblies. As a rule, ejidatarios transfer the entitlement of their individual plots to single heirs only after they die (the parcels are therefore not subdivided). However, individual certificates can also be transferred and sold to other people provided this is approved by the ejido general assembly. Since 1992 when the Constitution was changed, these parcels can be unincorporated from the ejido (privatized) (Cornelius and Myhre, 1998; Rico Garcia-Amado et al., 2011). This reform permitted more rapid land use change in specific areas, such as those close to the coast with potential for tourism, or for housing where the ejidos are adjacent to urban areas. Although the figures are dynamic due to reforestation, deforestation and privatization of land, previous studies indicate that ejidos own around half the territory of the country and 80% of Mexican forests (Barnes, 2009; Rico Garcia-Amado et al., 2011). There are parts of the territory remaining as government property. In a few cases public areas result from the public purchase or private donation of land for the creation of natural protected areas; in these cases the provision of environmental services can make use of policy options other than incentive-based mechanisms (e.g. management of protected areas).

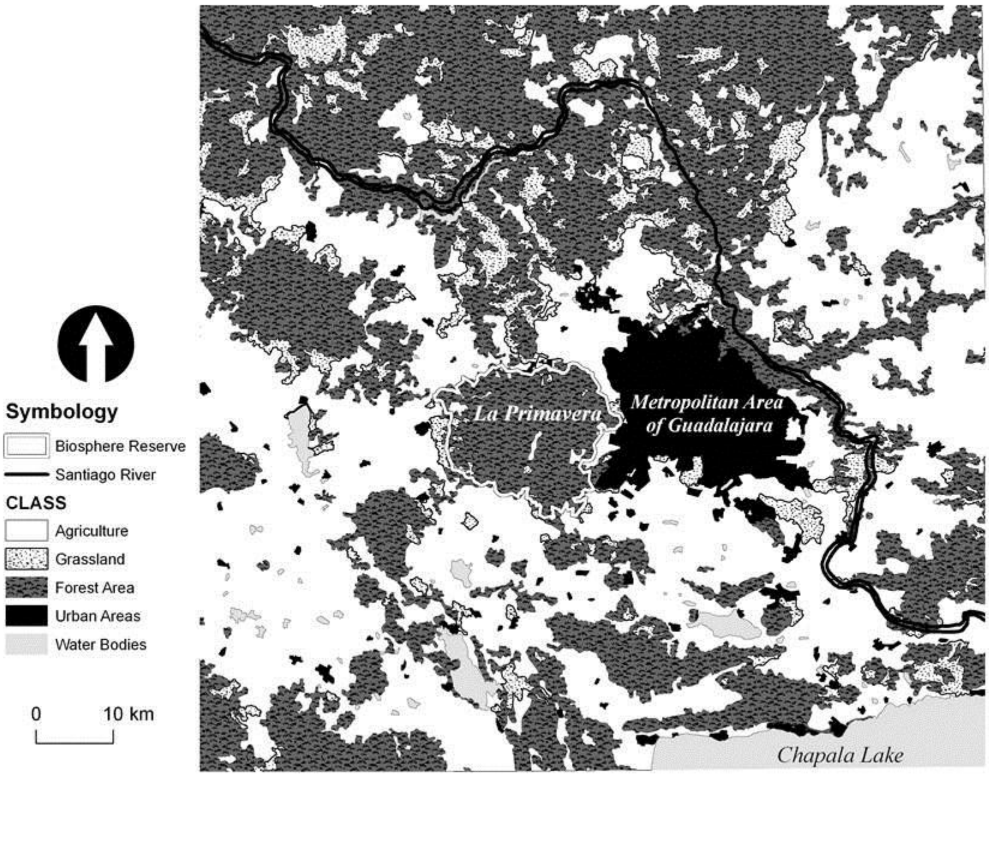
8.3.3. Case Study

The study area is the La Primavera forest in Jalisco, together with surrounding areas of forest patches up to 80 km away (Figure 8.1). The total area is around 1.5 million hectares. The main vegetation types in the area are oak-pine mixes, dry tropical deciduous forests and grasslands interspersed with agriculture. La Primavera forest (30,500 ha) was established in 1981 as a protected area and in 2006 it was declared a Biosphere Reserve by MAB-UNESCO (CONANP, 2000; UNESCO, 2011). On the eastern border is the city of Guadalajara, the capital of Jalisco and the second most populated metropolitan area in México, with around 4.4 million habitants (INEGI, 2011a). Proximity to and accessibility from the city increases the perception and valuation of environmental services (e.g. contribution to air quality) and recreation among the local population. However, it also increases the value of the land for housing development in the parts of La Primavera with access to the city.

Guadalajara has followed a disordered urbanization process in the recent decades, particularly in the metropolitan municipalities of Zapopan, Tonala and Tlajomulco. Zapopan's population increased by one million in 1970-2010 (INEGI, 2011a). In the same period the Tesistan Valley in Zapopan, once one of the most productive agricultural areas in México, saw its agricultural area shrink from 28,000 hectares to around 13,000 ha (Inforural, 2007). Tonala's population grew almost twenty fold from 1970 to reach 478,789 in 2010 (INEGI, 2011a) and urbanization buried the best clay mines from which traditional local artisan pottery was made, for which the region is famous (Loera, 2005). Most recently urbanization has been focused in the southern municipality of Tlajomulco, whose population increased at a mean yearly rate of 12.5% from 2000 to 2010 (INEGI, 2011a). In Tlajomulco more than 290 new housing developments, some of them consisting of more than 15,000 houses, were built during the last decade many of them without appropriate urban services (Informador, 2008; Perez Vega, 2012;). During 1997-2007, around 4,300 hectares of ejido land were sold, mostly to non-ejido buyers in the peri-urban municipalities of the metropolitan area of Guadalajara and about 4,200 ha were privatized (INEGI, 2007b).

In regions more distant from the urban area, grazing and commercial agricultural practices are common (*e.g.* sugar cane, agave for tequila production and maize). Land use changes outside the protected core part of the reserve, and the construction of roads around it, are isolating La Primavera and interrupting natural wildlife corridors to other forested areas. This is likely to compromise the long-term viability of populations of vulnerable wildlife species (*e.g.* large wide ranging carnivores such as the Puma, *Puma concolor*). The research presented here is part of a broader project funded by the Darwin Initiative, investigating the role that market-based mechanisms might have in the conservation of wildlife corridors and rural development (Balderas Torres et al., 2009). Here we aim to identify the potential of incentive-based mechanisms to promote the provision of environmental services in the region.

Figure 8.1 Study area presenting La Primavera and the Metropolitan Area of Guadalajara. Land uses and vegetation types grouped into broad classes based on INEGI, 2010.



8.4. Methods

8.4.1. Choice Modelling

Choice modelling (CM) is a stated preference technique founded on demand, welfare and consumer theory (Lancaster, 1966) and the random utility model (RUM) (McFadden, 1974). It was first developed for marketing and transportation studies and is now increasingly used in environmental non-market valuation (Bennett and Blamey, 2001; Hoyos, 2010). It allows the valuation of changes in environmental goods and services, or policies modifying their level of provision. In CM, respondents choose between hypothetical scenarios that vary in their specific characteristics, which are described by different attributes. In this case we investigated how the payment level, the length of the PES contract and the offer of other co-benefits increasing local human and productive capitals affect the preferences of landowners for PES programs.

In CM it is assumed that choices made by landowners maximize their utility (Bennett and Adamowicz, 2001). The choices are analyzed in econometric models representing the utility of an individual. Most econometric models consider an additive utility function where the attributes used in the choice experiment, individual characteristics and alternative associated constants (ASC) describing different scenarios are used as independent variables (Bennett and Adamowicz, 2001, Hoyos, 2010). The RUM implies that there is a stochastic component denoted by an error term. The commonly used multinomial logit model (MNL) assumes that this term follows a Gumbel distribution (Louviere, 2001; McFadden, 1974). This assumption imposes the restriction of independence of irrelevant alternatives (IIA) that can be diagnosed through the Hausman-McFadden test (Hausman and McFadden, 1984; Maddala, 1983). Heterogeneity in the sample and tastes of the participants may cause violations to the IIA assumption in which case the model may produce biased parameters (Ben-Akiva and Lerman, 1985; Bennett and Adamowicz, 2001).

CM allows the assessment of trade-offs among the different attributes of the experiment (Bennett and Adamowicz, 2001). As one of the attributes in a choice experiment is a monetary component, this allows the estimation of implicit prices, by dividing the parameter of a given attribute by that from the monetary one (Rolfe et al., 2000). In this research we utilize a MNL model with an additive utility function including the attributes of the scenarios. For a more detailed description of CM please refer to Hoyos, (2010) or Rolfe et al., (2000). We estimated an MNL model to obtain the implicit valuation of the co-benefits offered and the project duration (part worths); and used the bootstrap method of Krinsky and Robb with 7,500 iterations to create 95% confidence intervals for these values (Krinsky and Robb, 1986).

8.4.2. Survey design and Application

The survey posed a hypothetical situation in which a non-governmental organization (NGO) develops projects for conservation and rural development. The NGO would receive resources from private companies and citizens and invite landowners/ejidos to participate in a PES project. The benefits that the participants could receive were a cash payment and a set of co-benefits, over a given period of time. It was proposed that the NGO would help to improve the health and education services for the participants (by paying health insurance fees and hiring high school teachers for the service of the participants and families). Alternatively the NGO could help participants to get jobs and start small business by providing consultancy and financing. Conditions for participation in all cases included: (1) a specific forested area should be conserved or restored and monitored; and (2) measures should be taken to prevent and control fires/pests, grazing, hunting and illegal logging. The commitments and responsibilities would be specified in a collaboration agreement with the NGO and no penalties were referred to or included.

8.4.2.1. Choice Sets

For the design of the choice sets the research team selected the attributes and levels jointly with local experts; a pilot was done among key landowners which were interviewed to identify their interests and needs. Three attributes were chosen: cash payments, with four different levels ($31, $71, $117 and $165 per hectare per year); project duration (5, 9 or 17 years), and three levels for the potential co-benefits. The baseline was where no co-benefits were offered in terms of health and education services and employment/productive projects. An orthogonal main effects design generated 16 choice cards. Twelve choice sets each presenting two project proposals and one opt out for those deciding not to participate in the program were prepared in two questionnaires. Questions were designed to maintain a balance between the different levels of attributes; for this eight cards were included two times. In order to reduce the presentation of dominant options, the choice sets were prepared aiming to present options generating similar aggregated economic values. Because of the heterogeneity in the size of the properties we decided not to include an attribute specifying the area of forest to be committed for these practices. Instead, this issue was explored in the follow-up questions.

8.4.2.2. *Application*

The survey was carried out among 161 ejido and non-ejido landowners located in La Primavera and related wildlife corridors up to a distance of 80 km from the Reserve. In the study area there are around 90 ejidos, nine of which were selected at different distances from Guadalajara for the study. Ejido committees were contacted to present the research and invite them to participate. Ejido members were contacted in their monthly meetings. Non-ejido landowners were contacted through the regional association of private landowners of Jalisco. The list of representatives in each municipality in the study area was consulted to contact the registered landowners. Surveys were applied anonymously, in person, on an individual basis. Before applying the survey, background information and the proposed scenario were described. The information presented to the participants included, firstly a brief background about the goods and services produced by forests, and then the problems due to deforestation and land use change and the initiatives developed through public and private PES programs in México and different countries. The scenario and conditions for participation were also described. Participants were then presented with the choice sets. After the choice sets we included follow-up questions asking if the respondent would participate if the project became operational, in which case they were asked how much land they would like to include in the project. They were also asked if they would reforest non-forested areas (*i.e.* agricultural lands and/or grasslands) in order to integrate them in the project, or if they would be willing to adopt other agroforestry practices (*i.e.* living fences, windbreaks). Respondents from ejidos were asked if they would agree to include communal forested areas in the project. In order to get proxies for opportunity costs, we asked about the activities their properties are currently used for, and the expected prices at which land is sold in the area where the land is located. Other questions captured general socio-economic and demographic information. Later, in a geographic information system (GIS), we estimated the Euclidean distance to the metropolitan area of Guadalajara.

8.5. Results and Discussion

8.5.1. Sample Characteristics

Table 8.1 General statistical information of the sample.

	Mean	S.D.	Range
Age (years)	58.1	13.3	20 - 87
Household Size (members)	4.3	2.0	1 - 14
Education (Class) [a]	1.88	1.46	0 - 5
Income (Class) [b]	2.00	1.02	1 - 4
Income ($/cap-day)	5.10	4.54	1.39 - 36.43
Distance from Guadalajara City (km)	42.4	21.0	0 - 74.9
Land Price Forest ($) (n=42)	83,000	331,500	1,500 – 2'200,000
Land Price Non-Forest ($) (n=100)	66,500	269,700	1,100 – 2'600,000
Forest Area Owned (ha) (n=82)	33.7	75.4	0.2- 450
Agricultural Area Owned (ha) (n=139)	11.6	20.8	0.1- 180
Grassland (ha) (n=23)	14.5	15.7	1.0- 56
Total Area (ha)	30.6	71.1	0.1- 550
How much area would you commit if the project was implemented? (ha)	14.5	34.1	0 - 225

[a] Education classes: 0) None, 1) Elementary School, 2)Jr. High School, 3)High School, 4) Technical Studies, 5) Undergraduate
[b] Income classes 1) below $295; 2) $295-$590; 3) $590-$1100; 4) >$1100.

Surveys were carried out between March and August 2011, involving landowners in the La Primavera biosphere reserve (n=28) and in the biological corridors (n=133). 127 surveys were completed by ejidatarios and 34 by private landowners. Table 8.1 presents the basic characteristics of the sample. The total area held by the participants was 4715 ha. The total area belonging to the nine ejidos visited was 34,440 ha of which 11,440 ha are common land (RAN, 2011). In our sample 55.9% of the respondents held forested land; the remaining percentage did not have forested areas but agricultural parcels and/or grasslands. Even when participants did not have forested properties they were interviewed to investigate their preferences and to explore if they would reforest their properties in order to participate; when these participants were part of an ejido they were asked about the potential enrollment of communal forest areas. Factors affecting the perspectives for reforestation can be used to analyze the potential to restore the wildlife corridors and sequester carbon. With respect to current use, 75.8% of the respondents indicated that they used their land for productive cash activities (*e.g.* sugar cane, agave –tequila-, maize); 47.2% indicated that part of the production was also for their own consumption in the household and 7.7% had participated in the national PES program. In our sample 6.3% of the participants were females, 9.4% were single and 96.2% were economically active. The participants were, therefore, predominantly relatively old married males, which is consistent with other studies of Mexican landowners in rural areas in México and other countries (*e.g.* in the US, Dickinson et al., 2011).

8.5.2. MNL Model and Implicit Prices

Table 8.2 presents the MNL model, no violations with the IIA assumption were detected after the Hausman-McFadden test was applied. An ASC for the status quo alternative was included (opt out), this permits differentiating the effect of the options offering only the cash payment from that of the opt out. Responses of participants who found the questions confusing (3.1%) or those deciding not to participate in the PES in the six choice sets (protests) (6.2%) were not included following standard methods (e.g. Glenk and Colombo, 2010; Scarpa et al., 2009).

Table 8.2 MNL models.

	MNL Model
ASC Status Quo (Not to Participate)	-2.5576 (0.1307) ***
Payment ($/ha-yr)	0.0069 (0.0012) ***
Duration (yrs)	-0.1176 (0.01155) ***
Co-Benefit 1 (None)	-0.0049 (0.2452)
Co-Benefit 2 (Health and Education)	0.4080 (0.1868) **
Co-Benefit 3 (Productive Projects)	0.7093 (0.1843) ***
Valid (n)	2915
pR^2	0.425
Model Fitting Information (d.f.)	1010 (6)***

*** Significant at 99% Level.
** Significant at 95% Level.
Standard Error in Parenthesis.

The pseudo-R^2 is within the recommended values and the coefficients obtained are highly significant and with the expected signs: higher payments and shorter project periods are preferred. The projects offering co-benefits are more highly valued than the option where only the cash payment is offered (the coefficient for Co-Benefit 1 is close to zero, negative and statistically not significant).

Considering the coefficients obtained in Table 8.2 as the proxy for the probability of participation, the odds of joining the PES increase by about 0.7% per dollar offered per hectare per year. Respondents preferred shorter projects to the certainty of predictable payments over larger periods of time; this is in agreement with other cases reported in the literature (e.g. Markowski-Lindsay et al., 2011). Each extra year in the PES agreement reduced the odds of participation by 11.7%. Offering health and education co-benefits increased the chances of participation by 40.8%, on the other hand offering aid for employment and productive projects increased the chances by 70.9%; this implies that if a project includes both types of co-benefits this might take the odds of participation above 100% independently of the payment level. The implicit prices for the different project attributes are presented in Table 8.3.

Table 8.3 Implicit Prices for the different attributes with 95% Intervals, Krinsky and Robb method.

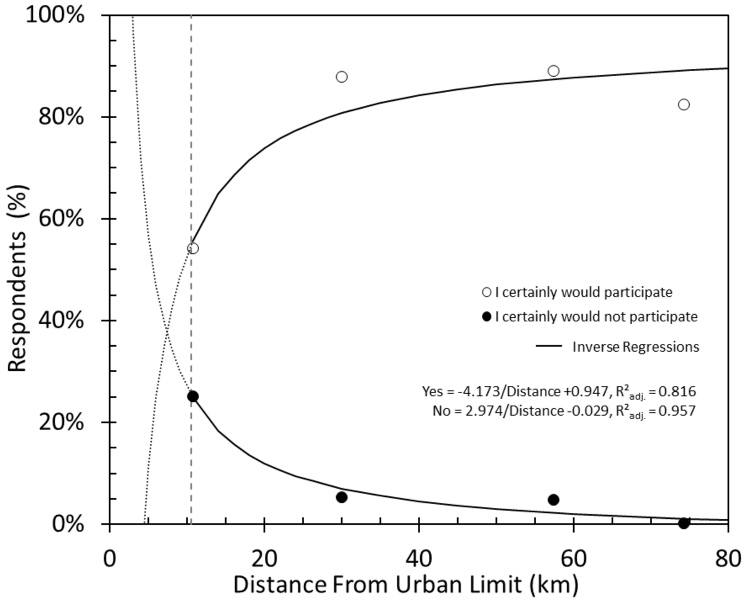
Attribute	**Implicit Prices (95% C.I.)**
Duration	-$17.08 (-$27.72, -$11.38)
No Co-Benefits (None)	-$0.71 (-$56.68, $93.25)
Health & Education	$59.30 ($5.68, $156.17)
Employment& Productive Projects	$103.09 ($40.92, $216.75)

If a project was to rely only on cash payments, the yearly payment per ha should be $145 to increase the odds of participating to 100%. The additional payment required to increase the chances of participation in a project including support for employment and productive projects would be of $42/ha-year.

8.5.3. Urban Opportunity Costs and Potential Participation

Table 8.4 shows the potential for participation among respondents across the whole sample if the project proposed became operational. There is high potential for participation among landowners, although 9.3% expressed overall negative opinions on participation. The potential for participation was explored in relation to the distance to Guadalajara (Figure 8.2).

Figure 8.2 Potential participation as function of distance to the limit of urban area.



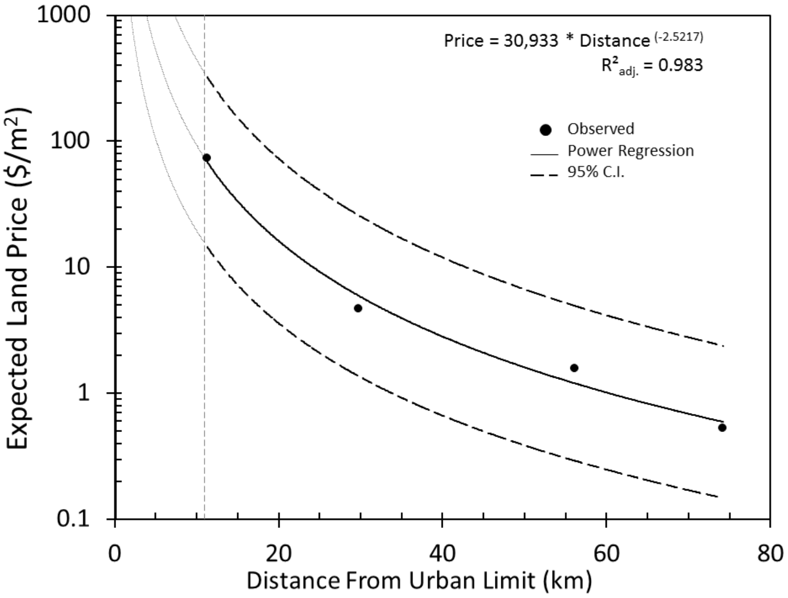
The two curves in Figure 8.2 are complementary and fit an inverse relationship well, indicating that landowners very close to the city are less likely to participate, *i.e*. the probability of participation increases with distance. Although no interviews were made in areas at distances closer than 8 km to the city it can be seen that between the protected area and the western urban limit there is a buffer of around 5 km where there are no remaining forests (Figure 8.1); these revealed decisions over land use support the specification forms presented in this figure. The regressions imply that at a distance of 5 km or less from the city there would be no interest in participating in PES; however, the dashed lines are included to delimit the valid distance range for the data in the sample. The forest cover in La Primavera has been preserved thanks to the status of National Protected Area and Biosphere Reserve. This status prevented a proposed plan to create a large housing development in it during the 1970's (Ciudad Primavera). Nevertheless, private landowners and ejidos were not compensated in any form when La Primavera was declared a protected area. Pressures for development still persist; and there is a proliferation of illegal construction of country houses inside the Reserve that are under litigation (del Castillo, 2011a). The data reported by respondents on land price was also classified by distance to assess urban opportunity costs (Figure 8.3).

Table 8.4 Answers to questions exploring the potential for participation.

If the Project becomes operational would you participate?:	Response (%)
Certainly Yes	82.6%
Probably Yes	8.1%
Probably Not	0.6%
Certainly Not (Not Answered)	8.7%
Would you support that communal areas join the project (ejidos)? (%) (n=127)	97.6%
What is the planned land use for the future in your land? (10 years)	
Agriculture (%)	71.4%
Businness/Development (%)	8.1%
Environmentally Friendly Productive Projects (%)[a]	22.4%

[a.]Ecotourism, vermicomposting, reforestation.

Figure 8.3 Land price and distance to the urban area (note logarithmic scale of the land price axis).



The data fits a power relationship between distance and land price indicating that the pressure of urban development will be far more intense in a radius up to 20 or 30 km from the urban frontier. This is in agreement with the implications of Figure 8.2. The opportunity cost of land in the vicinity of the city would be extremely high in comparison with the incentives that could be offered by voluntary programs such as PES. As in Figure 8.2, there are no data points for distances below 5 km that could confirm the curve specification in areas closer to the city; again the dashed grey lines are included to describe the general trend that could be expected within the most proximate area to the city outside the distance range of the data collected. Although in practice it is unreasonable to expect that price for land will tend to infinity, it does increase considerably more in these closer areas when urbanization has been authorized. Moreover, the function will present the trend of the price similarly to other cases where the value of scarce resources is estimated, e.g. Costanza et al., 1997, assumed that the price of an environmental resource will tend to infinity when its supply tend to zero. However, the equation in Figure 8.3 performs well in estimating the opportunity costs associated with land price within the valid distance range.

Although the prices of new housing developments may not be comparable to land prices, since they include the cost of construction, from Figure 8.3 it can be seen that even if the construction of new houses broke-even, the profit made when land bought at low prices is sold at the peri-urban market price is potentially enormous. Speculation in the real estate market might contribute to the disordered peri-urban growth experienced in the last few decades. Effective controls over land use change, particularly close to urban areas, are an essential precondition for the provision of environmental services; otherwise the landowners' expectations of urban development will prevent participation in schemes aiming to value them. This is particularly critical in hotspot areas for biodiversity such as La Primavera and its unprotected wildlife corridors, given its proximity to Guadalajara. In fact before the creation of the protected area there were plans to build high profile housing development inside of what later became the Reserve (Figure 8.4)

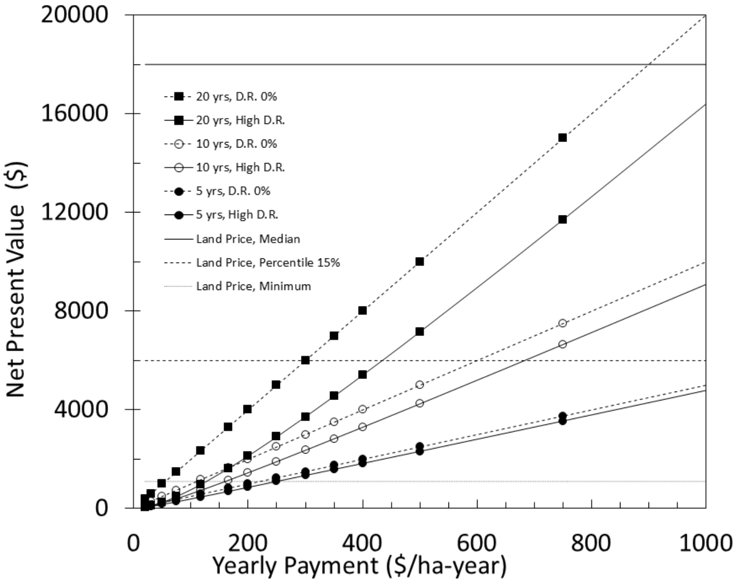
Figure 8.4. Old signpost inside the Biosphere Reserve; construction plans in the area before the creation of the reserve included a golf course and an airport (Photograph taken by Arturo Balderas Torres).

8.5.4. Implications of Offering Higher Payments in PES

Landowner's participation in PES could be increased if higher cash payments are offered in areas with higher opportunity costs. However, if higher payments are offered it can be the case that the net present value of the incentives paid can overcome land prices (Sullivan et al., 2005). This can compromise the efficiency of the program in the long term if high enrollment rates are required since purchase of land for conservation may be the least cost option in areas with low opportunity costs (Figure 8.5).

In Figure 8.5 the horizontal lines represent the land prices per hectare for the minimum land price reported, the lower 15% percentile and the median along with the net present value of payments in PES for different project durations as function of yearly payment levels. The net present values are estimated without discounting and using a discount rate of 7%. Discount rates from 4 to 6% have been used to estimate the net present value of incentives for forest banking (Sullivan et al., 2005); here we use a slightly higher figure to account for a lower economic development. The minimum price of land documented is equalized by PES projects paying between \$55 to 250/ha-year depending on contract length and discounting; the payments made by some PES programs in México are within this range (*e.g.* Pro-Bosque). Likewise the net present value of PES would match the value of the 15% percentile of land prices for payments in the range of \$300 to \$1250/ha-year.

Figure 8.5 Net present value of PES for different project durations and discount rates as function of yearly payment and comparison with land prices.



Buying land for conservation may be a more cost efficient option in the long term, but will be highly controversial. In rural areas, especially in those located away from cities, land is one of the most important productive, social and cultural assets. The comparatively lower land prices will be influenced by the local poverty context (Martinez Alier, 2004). If the payments set are a function of opportunity costs, they will systematically offer lower incentives in poor areas. The search of lower payments when aiming for cost efficiency should hence be carefully assessed; especially considering the benefits and savings that project intermediaries and buyers/users of the services may be obtaining. The relative balance between cash and in-kind payments in incentive-based mechanisms should be also carefully considered in such a way that the interests of the communities/landowners providing the environmental services and those of the financing bodies/users of those services are fulfilled; in any case the importance of each type of benefit could be negotiated as part of the PES agreement itself. How such win-win negotiations can be achieved in cases where the power relations may be very unbalanced is an important area for further research. Results presented here imply that although full opportunity costs are not covered, the value of pro-development interventions may increase the probabilities of enrollment.

Although the general purchase of land for conservation can be contested on political, social and economic grounds, it cannot be ignored that when opportunity costs of land increase (due to urban expansion, or creation of infrastructure), landowners might sell the land, as the process of urbanization in México after the constitutional reform and the case of Guadalajara show. In these cases strict land use regulation is required otherwise voluntary participation on incentive-based mechanisms will not suffice to ensure provision. The purchase of land for the provision of environmental services can offer a long-term solution in specific fragile or hotspot areas in exceptional cases *e.g.* wildlife corridors to prevent local extinctions.

8.5.5. Potential Enrolment into PES in the Study Region

Aside from the effect of Guadalajara's urban opportunity costs, there are positive scenarios for participation in PES in forested areas in the region. This is particularly noticeable for ejido communal areas since 96.7% of the responses were positive about their inclusion into PES. When participants were asked if they would reforest areas not currently forested (*i.e.* private land and individual ejido parcels), 26.8% answered positively indicating they would afforest grasslands that are used for grazing. This could have been affected by a drought in 2011which reduced livestock profitability (Toledo, 2012). Agricultural areas would not be afforested: in the region, prices for sugar cane were around $48/ton and for maize $400/ton and yields were 120ton/ha and 10 ton/ha respectively. However, the potential for agroforestry is high since 96.4% of those owning agricultural areas were positive about planting trees as windbreaks. This indicates that agroforestry practices may be attractive for landowners since they do not require full land conversion and may thus represent a viable option to enhance certain environmental services (*e.g.* carbon sequestration) (Balderas Torres et al., 2010a). Afforestation of grasslands and establishment of windbreaks can be funded through alternative sources of income in carbon markets for forestry offsets.

Currently there is a PES-like project under development in the area based on the results of the project funded by the Darwin Initiative (a brief description is included in the Appendix presented in Section 8.7 of this chapter). The project includes the conservation of about 1,100 ha, and reforestation of a further 100 ha in one of the wildlife corridors. It also includes pro-development interventions (*i.e.* a development community center, tree nursery, computer center and high school facilitation). The budget required for ten years of operation of this project is around $125/ha-yr. This is in line with the higher end PES programs in México; moreover, it is important to note that although the associated pro-development activities represent an important share of the costs (close to 50%), the social benefits expected from them can offset and exceed the overall costs of the project.

Overall in the study area (Figure 8.1), the development of a PES targeting existing forested areas would require $16.3 million per year at the current payment level of the national PES program, ($22.2/ha-yr) or close to $90 million at the rate expected for the pilot project. Pro-development interventions could benefit over 250,000 persons living in around 400 rural settlements in the region (100 to 2500 inhabitants). The total population in the area, excluding the metropolitan area of Guadalajara is around 720,000 (INEGI, 2011a). Maximum potential implementation for windbreaks through reforestation would be around 112,000 km (considering the perimeter of average parcels of 4 ha). If one quarter of the grasslands were reforested this would represent around 40,000 ha of new forests. For the purposes of biodiversity conservation, particular attention should be given to the areas linking La Primavera to other forested areas;

although these may represent only around a thousand hectares, as they are critical for the movement of wildlife.

8.6. Conclusions

Rural areas tend to maintain greater levels of natural capital while urban areas concentrate assets and expertise around financial, productive and institutional human and social capitals. PES and market mechanisms address this dichotomy, focusing on the valuation of natural capital to link the users of the environmental services in developed areas with the providers in rural areas. These interventions are devised to deal with environmental externalities commonly considered by economists to represent market failures. However, poverty can also be seen as a failure to generate and maintain adequate levels of human, productive, social and financial capitals. An integrated strategy to valorize environmental services could include mechanisms not only to ensure the flow of natural services from rural to developed areas, but also to transfer resources specifically linked to human, social, productive and financial capitals into rural areas appropriate to the local contexts while ensuring the provision of environmental services. Results of this study show that landowners prefer PES schemes including co-benefits that increase local levels of human and productive capital. Including the co-benefits may reduce the importance and dependence on cash payments and would increase the chances for participation; however, we consider that the mix of cash and in-kind compensation should be negotiated by the financing body and local providers as part of the agreement looked for in market-based mechanisms. The potential participation diminishes in the presence of high opportunity costs from urban areas. In these areas benefits and co-benefits offered by PES projects might not suffice to prevent forest clearance. Here, the critical precondition for preventing land use change would be strict land use regulations recognizing the value of the environmental services.

8.7. Appendix: Implementation Project.

Although it was not planned as part of the research, the findings produced by this research have helped to implement one project in La Primavera area, which exemplifies the bargaining process between providers and users of forest carbon services. In collaboration with the personnel of La Primavera, in 2009 the author got in contact with a local NGO (Fundacion Ecologica Selva Negra), which is the social and environmental non-profit organisation financed by the worldwide renown rock band Maná, originally from Guadalajara, to analyse the potential of a project for carbon sequestration. Since 2008 the band was planning a world tour and through the media became aware of the development of projects in voluntary markets to offset carbon emissions; for a time they had been thinking they should *do something about it* considering the potential impacts of the tour. Thanks to the personal bonds between the NGO director and band members with the Knowledge and Wildlife Director of La Primavera, during a casual encounter they expressed this interest; and the Reserve's officer facilitated the contact with the project. The author, in collaboration with students and lecturers from the local university ITESO, collaborated with the NGO to set the basic guidelines for the development of a reforestation activity. The first step was to estimate the carbon emissions of the tour (Manzano and Balderas Torres, 2009); based on this, different options for mitigating the impacts including existing markets were considered. The required area for reforestation based on the data from the forest inventory was estimated (60 to 100 ha). Basic implementation and transaction costs were estimated through cost analysis techniques (e.g. Balderas Torres et al., 2010a). The NGO decided to reduce transaction costs to channel more resources for actual implementation. The project focused on carbon sequestration since it was not clear how REDD+ was going to be implemented. Considering the fragility of the still functional La Primavera wildlife corridors (Figure 8.6) a decision was made by the team, confirmed by the NGO, La Primavera officers and the author, to explore potential for implementation close to Ahuisculco in Tala.

In 2010 the team members met various times with the authorities of the ejido of Ahuisculco. The purpose of the project was presented. The team asked the ejido for the owners of a target area close to one road. This land was privately owned and the ejido could not decide over it; however, the ejido members indicated they also had land that could be reforested for the project in a degraded part of the ejido's common area; the area had been affected by uncontrolled fires from nearby agricultural practices. Basic requirements for reforestation were identified with the ejido members. Additionally they indicated they were also interested in getting resources for the maintenance and conservation of around 1,140 ha of forest. When they were asked about other needs they had in the ejido they mentioned there were neither computers nor internet access for students at school; having this could improve education and future labour qualifications. The interest of the ejido was considered by the NGO and included in the project. Additional costs were estimated (i.e. conservation activities, a local centre for capacity building and an educational computer centre with internet access). The cost was portrayed in a PES like manner ($125/ha-yr during 10 years). The new budget lines accounted for about 50% of the total; thus the comparable cost was lower than some public PES programmes. If the project's social co-benefits were monetized these would offset the project's costs. The proposal was presented to the ejido assembly in February 2011 where it was unanimously agreed to authorise the ejido's authorities to continue the negotiations and prepare a formal agreement with the NGO. The project would produce more benefits than originally expected but scaled-up from 60 to 1,140 ha now including co-benefits.

Figure 8.6 Evidence of pumas in La Primavera. Left: photo by José Luis Leyva Navarro/Virgilio Tamez Orozco (Aura Jaguar A.C.). Right: photo by Karina Aguilar (La Primavera Office).

Note: After 30 years without direct evidence of the presence of pumas in La Primavera, from 2009 until 2012 pumas have been periodically photographed by camera traps set by independent researchers and La Primavera office in the Reserve indicating that wildlife corridors are still functional.

The formal agreement between the ejido and the NGO to define the precise activities, roles and responsibilities for the project during the next 10 years specifically for the reforestation activities was signed in July 2012; the first stage of reforestation activities were planned for the summer 2012. Additionally negotiations continue to integrate specific agreements for the other activities of the project. The implementation project can potentially surpass the target set by the NGO; however, this will depend on the effectiveness in implementation and follow-up. This project has helped to position in the public debate the need for the conservation of La Primavera's wildlife corridors, and the potential use of market mechanisms based on carbon accounting (e.g. del Castillo, 2011b; del Castillo, 2011c; del Castillo, 2012a). The NGO and the band presented the project to the president of México in 2011 (AP, 2011). The project was considered as innovative and the president endorsed it; thus the team met with officers from SEMARNAT and CONAFOR to identify coincidences with existing environmental programmes; CONAFOR provided fundamental technical information and guidance to refine the requirements and budget lines of the forestry part of the project. During this process the NGO has also established linkages with two local universities to develop initial diagnosis studies and projects (e.g. social development, water quality and wastewater treatment, domestic waste management).

8.8. Corollary: Comparison of WTA and WTP

The figures of the required demand and expenditure presented in the Corollary to Chapter 7 are used here to obtain the potential financing per hectare per year and compare it with the WTA by landowners and communities reported in this Chapter. Since the REL is not enough to prevent perverse incentives (1.84% versus the 3.7% required, Chapter 4), total carbon revenues are averaged in La Primavera considering the 30,500 ha. For this the total potential revenues from yearly production of forest carbon services are estimated at $10/tCO_{2eq}$ and divided by 30,500 ha. In this scenario it is assumed that landowners and communities would stop agricultural practices inside the Reserve to engage in carbon sequestration practices; while this is unlikely the impact on this analysis is minor considering the smaller contribution of carbon sequestration from reforestation activities to total carbon services (i.e. 11% compared to 52% from enhancements and 37% from reduced emissions). At a carbon price of \$10/tCO_{2eq} the average yearly payment would be \$67.1/ha-yr (\$53.9 - \$80.6/ha-yr), more than three times the payment in the national PES program. For landowners/communities only interested in cash benefits carbon prices from \$19 to \$28/tCO_{2eq} will be required to produce mean yearly payments of \$150/ha-yr; for those valuing multiple co-benefits cash payments at \$40/ha-yr could be obtained at \$5 to \$7/tCO_{2eq} if co-benefits are included as part of the market mechanism. Moreover, the fact that landowners and communities in La Primavera have enrolled in the national PES program indicates that at least some of them may accept lower payments equivalent to carbon prices from \$2.7 to \$3.3/tCO_{2eq}. Considering the development of the implementation project and the higher WTP in comparison to the lower WTA levels, when co-benefits are offered, and the lower level of the PES payment, there are positive views indicating there would be space for negotiation between providers and users in a local market; this could allow the groups concerned about cost and carbon (as described in Chapters 6 and 7) to participate in local markets. Moreover, the carbon prices required to generate the payment levels matching the higher WTA when no co-benefits are valued by providers are still within the higher limit of the 95% C.I. for the group with high income presented in Chapter 6 for the market stall sample.

9. Splitting the Difference: A Proposal for Benefit Sharing in REDD+[23]

9.1. Abstract

The objective of REDD+ is to create incentives for the reduction of emissions from deforestation and forest degradation and for the increase of carbon stocks through the enhancement, conservation and sustainable management of forests in developing countries. As part of the international negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), compensation would be estimated in relation to national performance but how these incentives will be channeled within countries has not been specified and there are concerns about how the benefits will be shared among different stakeholders. One central issue is that under the national approach good performance in one region can be offset by underperformance in other regions of the country thus preventing the generation of predictable local incentives. Other issues relate to the need to provide incentives to a wide range of stakeholders and to avoid perverse reactions. To address these and other issues we propose separating the accounting of reduced deforestation, reduced degradation and enhancement of forests. The local attribution of credits would be easier for carbon enhancement, and possibly reduced degradation, than for reduced deforestation, since carbon gains can, in principle, be measured locally in the first two cases, while estimating achievements in reduced deforestation requires a regional approach. This separation in attribution of rewards can help to create adequate incentives for the different stakeholders and overcome some of the problems associated with the design and implementation of national REDD+ programs.

9.2. Introduction

Under the UNFCCC policy on Reduced Emissions from Deforestation and forest Degradation (REDD+), national forest emission reductions will be calculated and developing countries may claim rewards or compensation in relation to such reductions. For this they will have to demonstrate that they have reduced the aggregated national rate of emissions from deforestation and/or degradation, and/or increased the rate of sequestration of carbon in forests (enhancement of forest stocks). Parties negotiating at the UNFCCC have been clear that national level accounting based on national reference levels is essential in the long run (UNFCCC, 2010a; UNFCCC, 2010b), although in early phases of implementation of REDD+, reference levels and accounting might be used at sub-national jurisdiction levels (for example, at province or state level or at the level of natural regions such as watersheds) (UNFCCC, 2012c).

[23] The material presented in this chapter has been published as Balderas Torres, A., Skutsch, M. 2012. Splitting the Difference: A Proposal for Benefit Sharing in Reduced Emissions from Deforestation and Forest Degradation (REDD+). *Forests* 2012, 3, 137-154; the Corollaries to this Chapter were not included in the aforementioned article.

Results based financing for REDD+ would be new, additional and predictable and would come from different sources (public, private, bilateral, multilateral) (UNFCCC, 2012a). It is not yet clear, however, whether the rewards/compensations will be in the form of carbon credits which may be bought and sold in a market or if financing would be channeled through funds. Decisions made at COP 17 leave the door open to both approaches (UNFCCC,2012a). The Cancun agreements indicate that REDD+ should follow a phased implementation: the first phase would be the preparation of national strategies or action plans, policies and measures, the second would focus on implementation with results-based demonstration activities, while in the third, systems would evolve into results-based actions which would be fully measured, reported and verified (UNFCCC,2011b). At this point, provided a system of safeguards and a national forest reference emission levels/reference levels (REL/RL) (or sub-national REL/RLs as an interim measure) are in place, results-based financing should follow (UNFCCC, 2012a; UNFCCC, 2011b). Table 9.1 presents examples of REDD+ activities that could be developed at the local and national levels in participating countries. Most of the activities developed by landowners and communities would be direct REDD+ activities. On the other hand some of the activities to be implemented by governments will be administrative and some of them may start as part of the readiness activities and would continue until the full implementation phase.

One question still to be resolved is how to distribute the financial benefits from results-based actions among the many stakeholders who may have contributed to reduce emissions and may have legitimate claims (Peskett, 2011). In particular, there are fears that in a national REDD+ program, a large part of the financial rewards would remain in the hands of government authorities and that local level owners and managers (often seen as forest based communities) might receive very little of the benefit (Peskett,2011; van Noordwijk et al., 2011; Brokhaus et al., 2009). This could potentially reverse the advances that have been made during the last two decades regarding decentralization of forest management, since governments may be interested in maintaining control over forest areas with the potential to produce carbon revenues (Phelps et al., 2010; Sandbrook et al., 2010). The objective of this chapter is to discuss what different options could be considered for distribution of the benefits associated with REDD+, in order to create effective incentives for governments, communities and landowners. We assume that participation of stakeholders in REDD+ would be voluntary and not mandatory, as suggested in some sources (Busch et al., 2012).

Table 9.1 Examples of REDD+ activities.

Scale	Implemented by	Examples of REDD+ activities
Local	Landowners, Communities, Projects	Sustainable management of forest (timber extraction, cattle exclusion); Sustainable extraction of products for subsistence (firewood, poles, fodder, *etc.*); Conservation; Agroforestry (e.g., coffee under shade); Change/intensification of agricultural activities; Enrichment planting/forest restoration; Local management (fire brigades, phyto sanitary control); Community monitoring.
National	Various national government bodies	Land use change regulation; Judicial control of illegal logging and fines; Regulation of carbon markets; PES programs; Design of agricultural subsidies; National fire brigades and phyto-sanitary programs; National forest inventories and remotely sensed analysis.

The structure of the chapter is as follows: we first explain the rationale for national forest Reference Emissions Levels and forest Reference Levels which will be used as baselines to evaluate the performance of REDD+. We then identify a number of challenges that arise as regards the distribution of rewards in a national system. We consider contrasting cases: one in which all the REDD+ financial rewards are considered property of the national government and one in which they are all distributed to the landowners and local communities. Neither system is satisfactory, for a number of reasons. We then describe how a mixed system can be designed to reconcile these challenges through differentiating crediting and attribution for the different elements in REDD+ (reduced emissions from degradation, reduced emissions from degradation and carbon enhancement). Finally we summarize our proposal for benefit sharing and present our conclusions.

9.3. National RELs and RLs

Under REDD+, reductions in gross emissions from deforestation and degradation will be quantified relative to a national forest reference emission level (REL) and/or forest reference levels (RL). The REL/RL represents what would have occurred without REDD+ intervention, based on observed historical trends and national circumstances, which are usually understood to include national plans for development, and it is clear that in the long run returns to REDD+ activities will be valorized on a strictly results based metric relative to these baselines.

Although the definitions and differences between REL/RL are still not completely established (SBSTA, 2011b), a REL is generally considered to refer to reductions in emissions only while a RL includes removals as well. It is clear that both refer to the yearly flux of carbon (tCO_{2eq}/year) (UNFCCC, 2012c). In Cancun it was established that national REL/RLs could be a combination of subnational REL/RLs (UNFCCC, 2011b). During the 35th session of the SBSTA, experts were in two camps concerning RELs and RLs. One group indicated that whether a country should use a REL or RL would be determined after balancing emissions and removals: a country having net emissions will use a REL while those with net removals will use a RL. The alternative point of view, and the one adopted in this chapter, is that countries could generate both a REL and a RL, accounting separately for emissions from deforestation and degradation in the REL, and the removals from conservation, SMF and enhancement in the RL. This would separate the accounting of REDD from the plus (+) (SBSTA, 2011b), and opens the possibility of separating the calculations of emissions from those of carbon enhancement.

Exactly how the REL and the RL will be established is not yet determined but the idea is that they will be based on historical trends at the national level as regards deforestation, degradation and forest enhancement, mediated by particular development factors relevant in each country. The decision adopted at Durban invites developing countries to submit a REL and/or a RL (UNFCCC, 2012c). As mentioned above, sub-national REL/RLs may be adopted as an interim measure, but for simplicity we will assume that the REL/RL is set up at the national level. The main reason why the policy stresses a national REL/RL (or one for large scale territorial units in the run-up phases) is to contend with the issue of leakage (Henders and Ostwald,2012; Aukland et al., 2003). Direct leakage occurs when activities that generate emissions of carbon are displaced to other locations as a result of a REDD+ activity in any given project area. A national baseline is considered to provide greater integrity with respect to the carbon results being claimed.

9.4. Challenges for Benefit Sharing under a National REDD+ Program

It is not yet clear whether internationally, financial benefits for REDD+ rewards will come through a market or through some kind of fund, and whether they will be seen as credits, rewards or compensation. Since the terminology may be confusing, we use the term "credits" as a form of shorthand to indicate the units of achievement in reducing emissions or enhancing carbon which will be valorized in some way under a results-based financing system. Although final text on the issue has not yet been agreed under UNFCCC, it is our understanding that international rewards (whether from a fund or a market) will be tied to national results or performance, as measured against the REL/RL, at least by Phase 3. Within a national program, "credits" could in practice be dispersed to stakeholders in the form of certificates (allowing stakeholders to sell these in a market or exchange them in a fund), as direct finance, or in other forms.

Making finance dependent on national performance however, raises the question of how to share REDD+ "credits" within a country. A crucial issue is that the system by which rewards are to be distributed is transparent, legitimate and in accordance with accepted rights, all of these terms being subject to local interpretation and definition. This is important since in order to mobilize action it is essential that REDD+ creates sufficient incentives for participation among landowners and communities, as well as government agencies. The UNFCCC is not likely to promulgate rules about how the carbon revenues are to be divided within a country, since this is a matter of subsidiarity. The Voluntary Carbon Standard has suggested developing nested sub-national REDD+ programs at different jurisdictional levels and including a buffer to reduce the risk of non-permanence (VCS, 2012); however, they recognize that once these jurisdictions are established, developers would have to design an internal allocation program for credits and the jurisdictions should specify how allocation decisions would be made (VCS, 2012). It has been also proposed that national REL/RLs could be aggregated bottom-up to generate a scale neutral architecture for REDD+ (Cattaneo, 2009) which as mentioned above is compatible with UNFCCC texts; however, internal methods to bear the risk of having emissions beyond the REL at the national level would be required, such as national, regional or individual shared responsibility mechanisms or a compulsory cap-and-trade system (Cattaneo, 2009), reduced dividends or debits under a stock flow mechanism (Cattaneo, 2008), or through compulsory tax/subsidy payments (Busch et al., 2012); however, the conditions for this type of methods may not be in place yet. While in theory the idea of having such internal schemes for compensating exceeding emissions in REDD+ countries may preserve the accounting integrity to appropriately compensate landowners performing well, in practice the conditions to implement this implicit taxes on land use emissions do not exist yet. First, there is no carbon tax for fossil fuel emissions thus it would be unfair to implicitly tax only land based emissions in developing countries; second, such tax or compensation scheme may not be effectively applied as it will be difficult to monitor and litigate thus it might not generate the necessary revenues to compensate the credits “lost”, just as nowadays there are problems with the implementation of existing land use and forest regulations; third it would be difficult to earmark this income in public budget to specific REDD+ programs; fourth the transaction costs of such distribution and accounting system are likely to be high; and fifth, punitive measures of this kind are unlikely to be acceptable to the general public, and are likely to raise public opposition to the whole idea of REDD+.

International REDD+ policy attributes all “credits” to the national or subnational level in the first instance. This is for carbon accounting reasons, since the rewards are a function of the achievements against the national/subnational REL/RL, which can only be determined at these levels. It could be argued that due to the issues of leakage and the need for clear national level action on REDD+, the credits should remain the property of the government, providing it with financial resources to cover the costs of designing and implementing national policies to strengthen forest governance and control illegal activities and emissions. In this scenario, the financial flows from REDD+ benefits might be used to cover the public costs of the design, consultation, establishment and monitoring of the REL/RL, the MRV system and the system to ensure compliance with environmental and social safeguards, but also perhaps to provide financial incentives to local actors, for example in the form of Payments for Environmental Services (PES).

The central control of REDD+ benefits however, raises the question of carbon property rights and legal ownership of the carbon “credits”. A large part of the literature in REDD+ supports the moral rights of forest owners, particularly communities, to the financial returns from sale of carbon credits (Pedroni et al., 2009; Cortez et al., 2010). Although the laws on property rights of individuals and communities to forest carbon have been established in only a few countries so far (Australia, Argentina), there are precedents that imply that carbon is akin to other tree products (Basnet, 2009); in most countries the products of trees belong to the owners of the trees. If this legal argument is accepted, it implies that all the “credits” should be re-distributed immediately from central government to the local stakeholders, commensurate with achievements at the level of the individual parcel or management unit, where the savings are actually being made. The corollary of this is that baselines would be needed at the level of the individual parcel or management unit, so that achievements could be assessed; while this may be feasible it may take some time until the information to do this at the local level is available as we discuss below. This however, ignores the fact that some REDD+ programs may take place outside the forest, for example in intensification of agriculture, and that tracing the impacts of this on the forest in order to reward the individuals involved will be impossible.

Hence, although the choice between these two positions may at first sight appear a simple matter of policy, in reality it is constrained by a number of important technical and political issues:

9.4.1. *The Need to Balance Carbon Accounts between Local and National Levels*

Under a national REDD+ program, at least when this is fully functioning in Phase 3, rewards will be delivered on the basis of overall national achievements against the REL or RL, which represents an internal balance of gains and losses over the whole forest territory. Good performance by communities or landowners in one region of the country may thus be cancelled out by losses elsewhere, only "residual" credits could be allocated (Cattaneo, 2009). This means that, in the worst case, landowners would not be entitled to compensation at all, even if the carbon losses in other regions were unrelated to leakage from the successful cases. This resembles the well-known local-scale problem of collective management of common pool resources, where individual benefits depend on the good behavior of all the actors, and the underperformance or negative behavior of a few can compromise the benefits for all. If the "credits" are to be attributed to the owners and manager of forest parcels, the challenge is how to manage expectations of these local level actors and ensure that despite the need for balancing overall accounts at the national level, successful participants are assured of receiving rewards commensurate with their own local achievements, since this is their incentive for participation and for good performance. In the VCS, this is dealt with through creation of a buffer (VCS, 2012), but to cover or insure against potential large scale losses at national level in many countries, the buffer would have to be of a considerable size, with payoffs to individual parcel owners being correspondingly reduced. Moreover, as noted above, at least in theory the possibility exists that overall national losses may completely outweigh gains in individual projects. Another alternative is the payment of internal compensation, or tax/subsidy systems for exceeding emissions (Cattaneo, 2009; Busch et al., 2012), however, ase mentioend above this type of instruments may be controversial.

A corollary of the need to balance the national accounts with the local is that benefits can only be calculated at the end of the accounting period, meaning that individual forest owners and managers, communities *etc*. will not be sure of the level of their reward until the end the of this period; and as noted already the size of the payments will be conditional on good performance elsewhere.

9.4.2. *The Need to Enable Independent Carbon Trading to Stimulate Investment*

Assurance that achievements at the level of the management unit will be rewarded is important not only for the owners and managers of forest parcels, but also for sponsors both domestic and foreign who want to finance decentralized REDD+ projects, and who may be an important source of up-front capital. Such investors need assurance that successful efforts will be rewarded, regardless of what goes on in other parts of the country. The interest of external sponsors and supporters brings with it pressure to allow at least some level of independent trading of "REDD+ credits" from project based activities. This follows from positive experience in the Voluntary Carbon Market in which REDD+/Avoided Land Conversion projects increased from 3 to 18 $MtCO_{2eq}$ per year from 2009 to 2010, representing 29% of the carbon traded in this market (Peters-Stanley et al., 2011). Carbon brokers strongly support the notion of independent projects and nested projects trading their own "credits", citing advantages of the private sector and this principle also has support from a wide range of international organizations and REDD+ observers (De Gryzde and Durschinger, 2010; Swickard and Carnahan, 2010). Thus the national approach to REDD+ accounting and internal reward distribution generates critical implications for the potential international finance of projects at the sub-national and local levels.

9.4.3. The Need for Budget for Public Activities under REDD+

If all financial revenues are made over to the local level actors, other stakeholders, principally the government agencies at various levels, will not receive any incentives and may therefore not be able to provide the support that is required in implementing key supporting activities. On the other hand, if all the funds are left in the hands of government, there are risks that the lion's share will be used for activities which do not result directly in carbon savings, rather than for payments to local forest owners and managers for their efforts. This could result in policy failure, particularly if the issue of carbon rights is raised, and if there is no transparency on how the revenues are utilized.

9.4.4. The Need for Clarity on Land Tenure and Associated Rights

In countries such as México, where almost all the forest is owned by communities or individuals, the legal position is clear, since the owner(s) of the land would presumably also have the right to rewards from "credits" generated by the property. However, in countries where most of the forest belongs to the government, but is (in places) managed by communities on an usufructuary basis or in other ways, rights to the carbon would need to be made explicit in the terms of the community management contracts or agreements, which in some cases already define rights to other products such as firewood, fodder and timber. This would involve negotiation, and communities may need legal support in making their claims in this respect. A not insignificant risk which is that the local attribution credits may intensify conflicts in areas which are already under legal dispute as regards ownership. It is even conceivable that the process of legalizing local tenure may be slowed down, as governments may be reluctant to grant tenure to local communities, given the potential of earning on carbon "credits" (Phelps et al., 2010).

9.4.5. The Problem of the Attribution of Reduced Deforestation to Different Forest Owners/Managers

In order to attribute rewards from REDD+ locally to the owners of trees, a major challenge is how to identify whom to pay for reduced emissions from deforestation. First of all, a baseline for deforestation at the parcel level would be required. Secondly, it would be necessary to identify exactly who would have deforested in a given crediting period (*i.e.*, in the counterfactual case) in order to attribute the carbon credits. In practice it is rarely possible to fulfill these two requirements; only in cases where the deforestation was planned (*i.e.*, officially sanctioned), but averted as a result of REDD+, would this information be known. In the vast majority of cases the location of future deforestation is not known, even when it is legal. Owners of land, whether individuals or communities, may decide to convert the forest on it at any point in time to agriculture or sell it for urban development; this is not "planned" in the sense of being pre-registered in any database. Areas owned by the state but managed by communities or by the state itself under "no deforestation" rules may at any time be illegally deforested, either by the community or by outside forces such as immigrant people and organized criminal groups or may be damaged by fires spreading from other properties.

For this reason, baselines for deforestation are usually constructed nationally and sub-nationally over large areas covering a large number of parcels and landowners, on the basis of the percentage of forest loss in the past, and giving the *probability* of deforestation of any one hectare within this area. However, at the level of the individual parcel, past deforestation events are unlikely to have followed a smooth historical pattern of the sort that could be converted into a simple projection into the future, particularly in small parcels such as those typically managed by communities. Clearance of a patch of forest within individual parcels or management units in any one year may well be followed by no clearances in next few years. In many cases it would be impossible to construct a deforestation baseline for any individual forest management unit, since the unit would be either forested or deforested.

Identification of who would have deforested in a given period, but has not, is an even greater challenge. For example, if deforestation is occurring in a given region at say 2% per annum, this is equivalent to two forest owners out of 100 clearing their land in any given year (assuming for simplicity that all forest parcels are the same size). The problem is that if deforestation is reduced or halted over the whole area compared to this baseline, it is impossible to know exactly which owners would have been going to clear their forest in any given year. All of them could claim that this had been their intention and therefore all could demand carbon "credits" equivalent to the emissions that would have occurred from their land, had they cleared it. But in fact according to the historical data, only 2 properties per year were "saved" from deforestation and internationally, "credits" will only be issued for the equivalent of 2 properties annually, not 100. If the yearly carbon revenues are divided equally among all the properties, (which would have to be coordinated and agreed through some umbrella organization), the payment would be negligible and most likely would result an ineffectual incentive.

The dilemma here is that under current policy, REDD+ rewards will be based on results within a given accounting period. Under this logic, it is not possible to look at the long term scenario, in which (at a rate of 2 parcels per year) all the parcels would be cleared in 50 years, and to pay "credits" to all the owners now in return for the promise to preserve all their stock over these 50 years, which would resolve the problem of identifying whom to pay. Apart from other considerations, results-based logic requires *ex-post* payments rather than *ex-ante*, and the present value of "credits" paid in 50 years hence would be too low to create a meaningful incentive now. In this context it may be noted that for a given parcel the maximum amount of credits for avoided deforestation that could be granted in the long term (50 years in this example) will be equal to the current level of carbon stocks. The maximum credits for avoided emissions would not be higher than the initial level of carbon stocks in the forest. A further issue making attribution of credits for reduced deforestation to stakeholders difficult is the fact that some REDD+ activities may be undertaken outside the forest, for example in the form of intensification of agriculture, which will reduce demand for forest clearance in the long run.

Quantitatively assessing the carbon impacts of each stakeholder in such a program would obviously be impossible, yet it would be reasonable for them to be rewarded for their efforts.

9.4.6. The Problems of Developing Baselines for Forest Degradation and Enhancement

If the "credits" for reduced degradation and forest enhancement are to be attributed to individual owners and managers of forest parcels, then achievements on these variables would need to be measured at the level of the parcel. There is a fundamental difference in our ability to assess reduced deforestation as opposed to reduced degradation/forest enhancement at the parcel level. As explained in the previous paragraph, deforestation baselines are constructed on the basis of probabilities across large areas, and although we may know the general tendency at this level, we do not know *which* parcels would have been deforested in the absence of REDD+. At the level of the individual parcel, particularly in small parcels of the type commonly managed by individuals or communities, the forest may be cleared in one go (no line of tendency), or in chunks over time which are large relative to the whole forest parcel, meaning that there is no simple line of tendency on which to construct a statistically acceptable baseline. Forest degradation and enhancement on the other hand tend to be continuous processes causing on-going changes in carbon stocks levels within forests within each parcel. For these, a baseline could in principle be constructed at parcel level showing the rate of change of stocks within the parcel, against which future rates of change can be compared. Unlike the case of deforestation, there is no ambiguity about which parcels have actually made achievements, although baselines would be needed to assess performance. The difference in our ability to assess deforestation and degradation/enhancement at the parcel level is thus related not to MRV but to the difference in the way baselines have to be constructed.

There are, however, problems associated with developing baselines for degradation at the level of the parcel, primarily because there may be no data available on past rates of degradation. Even at national level this may be a problem, since most countries have not carried out comprehensive and systematic forest inventories in the past. Where forest inventories have been carried out, they are generally aimed at providing information on average stocks over large areas, and cannot give reliable estimates for individual parcels since the spatial sampling grid is not sufficiently intense for this. Changes in canopy cover at parcel level can be assessed from a series of high resolution satellite images, although this would give only an approximation of changing biomass levels. LiDAR offers opportunities for better biomass assessments, but LiDAR surveys have has not been carried out in the past, and moreover, this information is very expensive. In other words in the early phases of REDD+, before data is collected in a comprehensive way, it will be rather difficult to assess historical changes in degradation rates at the level of the individual parcel (Herold et al., 2011). However, if data were available on carbon stocks in a given forest parcel over the recent historical period, it would in principle be possible to attribute "credits" to individual parcels; this could also be supported by data on estimated extraction rates for timber and firewood as proxies, using gain-loss methodology for example.

The remaining difficulty is the construction of a REL for degradation at the national level, which would be an essential prerequisite since, as with the case of deforestation, the achievements in reducing emissions from degradation will have to be balanced out across all forest areas in the country. Even with high resolution satellite imagery such as SPOT, it is difficult to derive data on degradation since some types of degradation involve loss of carbon under the canopy, which is not visible. During the 35th SBSTA session in Durban when these difficulties were discussed, some experts were in favor of using IPCC default values to estimate emissions from degradation at national level, rather than to exclude its accounting in REDD+ completely (SBSTA,2011b), although this would result in large uncertainty factors which will require correspondingly large margins for conservatism. Establishing a RL for forest enhancement at national level would face the same problems as a REL for national degradation; it would require data of growth rates of forest which are not available in most countries.

As regards forest enhancement, however, the question of baselines may be much simpler. At the level of the individual parcel, forest enhancement can be measured by taking forest inventories at the start and the end of the accounting period (data would be strengthened if intermediate measurements were also taken). The baseline would then in effect be set at zero at the start of the period, and any increases in stock could be "credited". Additionality would however, have to be ensured, since the area could have been in a process of recuperation before the start of the accounting period. For this, in areas that were under degradation prior to REDD+ management, a quantitative assessment of the REL would not be necessary, merely a verified statement that the area had been degrading, or was degraded but in a stable (non-growth) situation, immediately before the accounting period. It is important to note that in this case any measurable carbon enhancement would imply that earlier degradation has been reversed,

Table 9.2 Summary of challenges facing the public and the local attribution of REDD+ credits within national REDD+ programs.

Attribution of all "credits" to	Leads to the following challenges
National (Government)	Tree owners may oppose centralized control of "credits", claiming legal and moral rights over carbon benefits produced by their trees/forests; Uncertainty/lack of transparency about use of funds; Uncertainty about whether local owners/managers and independent project developers will receive any rewards and on what basis, hence possible lack of interest in participating; There would be no certainty for independently sponsored projects that they would receive rewards commensurate with their achievements in deforestation and degradation, hence such financiers may be discouraged from investing.
Local (Forest owners)	"Credits" for deforestation and degradation could only be calculated ex-post and any losses elsewhere in the country would have to be factored in to the rewards paid to owners and managers of individual forest parcels, meaning that their rewards may be less than the face value of their achievements; Payments could be made only at the end of the accounting period, which may discourage participation; Government would receive no financial benefits and might not have the resources to implement necessary supporting activities; Local attribution of credits may intensify existing conflicts over land ownership; In countries where forest ownership is informal, there may be legal problems attributing "credits" to the de facto managers; Governments may be reluctant to grant tenure to local managers, on account of the earning potential from carbon; It is not possible to identify within the accounting period precisely which parcels would have been deforested without REDD+, hence not possible to allocate the rewards to specific parcels according to their performance; Baselines for degradation at the parcel level would be required for assessing achievements, but there is little data available for this.

implying that both the avoided degradation and the enhancement could be "credited" at the level of the parcel. This would leave open the possibility that if the parcel had been under recovery prior to REDD+ management, "credits" could still be awarded for any increases in biomass stocks to the extent that the rate of increase can be proven to be greater than it was earlier. A RL at national level would not be necessary since leakage from forest enhancement is unlikely, once leakage from degradation is dealt with, and hence it would be possible to attribute "credits" directly to individual parcels without compromising the integrity of accounting at the national level.

Table 9.2 presents a summary of the practical challenges discussed in this section, in relation to attribution of REDD+ benefits to the national scale (government) and to the local scale (individual forest owners/mangers, communities), respectively. In the following section we propose a mixed reward scheme which can address many of these challenges.

9.5. A Proposal for Benefit Sharing

It is necessary to recognize that in reality, both direct forest management activities implemented by local communities/landowners and public policies promoted by government may contribute in reaching the national performance goals of REDD+ (Table 9.1), and that both may therefore have legitimate claims to benefits. Considering this, and the various other challenges identified above, we propose a mixed approach for the distribution of benefits, aiming to create appropriate incentives for a variety of stakeholders (e.g., landowners, communities and government institutions), according to their sphere of action in reducing emissions and enhancing carbon stocks in forests. Three different sets of accounts would be needed: landowners and communities could elect which of the three schemes they join.

9.5.1. Reduced Emissions from Deforestation

Since, as discussed above, deforestation baselines cannot be prepared at the level of the individual parcels managed by landowners and communities, but only at a much higher level of aggregation, we propose that all "credits" associated with reductions in deforestation should be accounted and attributed in the first instance to this higher level of aggregation, probably represented by a government administrative level such as a district or a region. A clear and transparent agreement would then be required, under which part of the related financial flow is assigned to government for costs related to support of the REDD+ program. This could be seen as a fraction on the total "income" from carbon revenues. The rest would be destined for payment of incentives to landowners and communities registered as participants in the Reduced Deforestation scheme. Since, as explained above, it is not possible to identify which individual parcels have in reality been saved from deforestation in any given period, the most convenient approach may be a flat rate payment per hectare to all participants that comply with management agreements in these areas (*i.e*., who do not deforest). This is in fact how most PES programs operate today; payments to participants are not proportional to individual results, but are given for compliance with practices which are considered to bring about the desired results, usually on an annual basis. It has considerable advantages in terms of transaction costs, since flat rate payments are much easier to administer than payments by results. A flat rate payment system may include differentiated payments, (e.g., higher payments in conserved forests and lower payments in degraded forests). Such schemes have been applied for instance in México where higher payments are granted to cloud forests in virtue of their higher hydrological services (Muñoz Piña et al., 2008). The financing could be based on the revenues from avoided deforestation, for instance following the "flow withholding and stock payment" by which a percentage of the carbon revenues are used to make payments proportional to carbon stocks (Cattaneo, 2009; Cattaneo, 2010).

To encourage participation, however, it may be necessary for governments to capitalize this program up-front, making regular payments to the participants who follow the rules throughout the accounting period, and recovering the funds only when the "credits" are sold or exchanged internationally at the end of this period. This would involve some risk to government, as would the fact that losses in relation the national REL in other districts or regions would have to be factored into the final calculation of "credits" available. However, the local level participants would be assured of fixed, if small, payments, provided they follow the management prescriptions.

It is clear that in areas where the rent for alternative uses of forest land is high, such payments will not be sufficient to prevent deforestation. In these areas, supplementary incentives and controls will be needed. The most important policy to control deforestation in areas of such high opportunity cost may be effective land use planning and control and a governance system strongly dependent on government norms and actions.

9.5.2. Reduced Emissions from Degradation

Reductions in degradation could be brought about by introduction of sustainable forest management practices by landowners and communities. Unlike the case of deforestation, baselines for reduced degradation can in principle be made at the level of the individual parcel, and achievements against these baselines can be measured. Nevertheless, leakage through displacement of the activities that cause degradation also needs to be considered. Degradation "credits" cannot be issued independently of the national accounting system, and losses and gains will have to be compared against the national REL. This implies that "credits" for reduced degradation, like those for deforestation, need to be attributed in the first instance to higher level administrative level, where the necessary adjustments can be made at the end of the accounting period. As is the case with reduced deforestation, a fixed proportion of the related financial flows could be allocated to the government to cover the transaction costs, and the rest distributed among the landowners and communities who have registered as participating in a management program to reduce rates of degradation in their forests or the PES. In this case, however, the payments could be made proportional to the actual reductions that individual management units have achieved, against their own individual baselines when they become available. This would require ground level monitoring, and payments that could only be made at the end of the accounting period when results are known. The immediate difficulty is that in the short term it may be impossible to construct either parcel level baselines or a national REL for degradation, given the lack of historical rate on degradation rates. Claims for "credits" on reduced degradation may therefore have to be postponed for several years until sufficient forest inventory work has been done, both at national level and at the level of the individual parcels or until a system of default values is agreed under the UNFCCC.

9.5.3. Forest Enhancement

In contrast to reduced degradation which requires historical data in order to be "credited", net increases in carbon stocks (forest enhancement) can be measured directly at the parcel level and can be monitored by local owners and managers (Thoumi, 2011). If a forest inventory is made within the parcel at the start of engagement in REDD+, and repeated at intervals, then growth in carbon stock can be simply assessed compared to the initial inventory, which becomes the parcel level baseline. Additionality could be proved using a qualitative assessment of the previous situation, as explained above.

Although countries can establish RELs at national level for deforestation and degradation and/or RL for forest enhancement, it is likely that most of the countries will develop first the REL since it may be years before RL can be developed, as growth rates of stock in forest are scarcely known at present. However, gains in carbon stock at the level of individual parcels could be "credited" and attributed directly to the owners and managers of these parcels, without reference to what is occurring in the rest of the country. As mentioned above, an assessment at the local level should be made to identify if an area was under degradation in which case there should be no need for a local RL to credit forest enhancement. In this case the parcel would have stopped degradation emissions but the landowner would not be receiving directly any credits for this, as described in the previous section. If areas showing net enhancements produce leakage through the displacement of previously degrading activities, which will certainly not always be the case, this will not affect performance in the region as long as the leakage is smaller or equal to the emissions that were expected in the parcel according to the REL[24](Thoumi,2011). The rewards for enhancements would be results based, directly proportional to achievements, but could only be assessed at the end of the accounting period. Also as pointed out earlier, measuring carbon enhancement in areas under degradation would be an incentive to encourage the definition of a local baseline for degradation as well.

Landowners in forested areas would thus receive flat rate PES type payments if they comply with the requirements of the program and could in addition receive revenues from carbon enhancements. The option as described above of setting higher rates of PES in forests with higher conservation value could help prevent perverse incentives. The two streams of incentives would be addressing different REDD+ elements, the PES accounting for reduced deforestation or degradation and direct carbon credits from enhancement. A summary of the main elements of the distribution system is given in Table 9.3.

[24] This is because the landowner of the specific parcel 'i', where the net enhancement is measured, would not be paid for the avoided emissions from degradation associated to his parcel; thus elsewhere in the region emissions could increase by an amount equal to the reduced emissions in parcel 'i' and still comply with the REL. In fact areas that were under degradation and where carbon enhancements are measured will create a 'buffer' of credits. If no leakage occurs and all other landowners comply with the REL, there would be a surplus of credits equal to the reduced emissions from degradation in areas with net enhancements which can be distributed accordingly *ex-post*.

Table 9.3 Proposed mixed scheme for the distribution of rewards in a national REDD+ program.

Crediting field	Reference for crediting/financing	Distribution of rewards
Reduced deforestation	Baseline at sub-national level (district/region), results subject to overall national achievements relative to national REL.	Part of the "credits" from regional reduced degradation used to finance flat rate PES payments targeting landowners and communities in areas threatened by deforestation; Part used to finance government support activities; The division between these two claims needs to be agreed and transparent; Up-front payments to forest owners and communities could be pre-financed by government and costs recuperated later from sale of "credits".
Reduced degradation	Baselines at parcel level and at sub-national level (district/region), results subject to overall national achievements relative to national REL.	Part of the "credits" from reduced degradation distributed to landowners and communities in proportion to their individual achievements (including through SFM) relative to parcel-level baseline. Payments at end of accounting period; Rest used to finance government support activities; The division between these two claim needs to be agreed and transparent; It may be many years before any rewards for degradation can be awarded, as development of baselines requires historical data which is in many cases not available at present;
Carbon enhancement	Baseline at the level of individual parcel. No national RL.	"Credits" from carbon enhancement attributed directly to parcel level; "Credits" can be sold by parcel owners independent of government RELs and independent of losses or gains in other parts of the country; Forest monitoring at start of period to establish baseline for stock level and at end to assess growth (*i.e.,* carbon achievements).

9.6. Discussion

The proposed scheme overcomes many of the challenges identified with respect to distribution of benefits within a national REDD+ program. This scheme for mixed incentives is based on realities as regards the possibilities of measuring carbon achievements and attributing these to landowners and communities, and on the need to balance carbon accounting at the national level. The separation of credits for carbon enhancement from those of deforestation and degradation, and attribution of forest enhancement solely to individual parcels creates the possibility for independent projects to orient themselves to the carbon markets directly, and a wide range of stakeholder could participate in this. The crediting of reduced degradation as soon as a national REL and parcel-level RELs for this can be developed, may offer another stream based on performance of landowners and communities in line with carbon property rights. The problem of identifying which parcels would have been deforested is solved by paying a flat rate PES-like payment (possibly up front) to all registered participants. By combining a flat rate payment for communities and land owners who do not deforest, and a results-based payment for reduced degradation, with independent, results-based forest enhancement "credits" at the level of the forest parcel, a more robust set of incentives would be in place.

As regards the share of the deforestation and degradation "credits" that government should be allocated compared to those used to cover payments to forest owners and communities, it may be important to distinguish between the roles of government at the national and the sub-national levels. Many of the governmental policies and actions (Table 9.1) will be implemented at national level and may have an indirect or diffuse effect on carbon stocks thus making it difficult to link them directly with any specific changes in carbon stocks. The national government will also face overhead and transaction costs related to the country's participation in REDD+ (setting up the RELs, implementing national forestry inventories, instituting monitoring of land use change using remote sensing facilities, developing and disseminating public information, capacity building, *etc.*). These costs are unlikely to be covered by results-based revenues from REDD+ "credits". Fortunately there are a variety of multi- and bi-lateral funds already available (the World Bank's FCPF program, UN-REDD, NORAD, *etc.*) for these purposes. Given the fact that REDD+ is likely to have positive spin-offs and reinforce existing policies in the forest sector, it is not unreasonable that further costs of this sort are covered by regular budgetary sources in most countries.

At the sub-national level (regional, district, municipal) however, government organizations will have costs associated with direct support to the participation of forest owners and communities in REDD+, for example in training, in monitoring, and in maintaining data systems for carbon accounting. Moreover, it is possible that government agencies themselves set up projects directly (reserves, conservation areas, *etc.*). Hence the suggestion that some part of the revenues related to carbon "credits" could flow to sub-national governments is not unreasonable. The proportion absorbed by government will vary from country to country. The most important point in this regard is that the level of the revenue used for such purposes should be determined through public debate, and that transparency in the use of all financial flows from REDD+ credits is maintained.

9.7. Conclusions

REDD+ is advancing in negotiations under the UNFCCC where the phases of implementation of national programs and the systems for MRV and the implementation of safeguards have been defined. However, how benefits will be shared between stakeholders within national REDD+ programs is still an open question. We argue that it is possible to design a rewards and incentives system in which both landowners and communities managing forests and local government agencies will receive a share of the financial flows from REDD+. A critical step to enable this is the separation of accounting for deforestation, degradation and forest enhancement, and the setting of baselines for degradation and forest enhancement at the level of the parcel or management units, while the baseline for reduced deforestation applies to the regional level. Separated accounting enables the independent attribution of carbon enhancement and (in theory at least) reduced degradation to local landowners and communities. Although it is not easy to assess the relative potential for generation of carbon "credits" from reduced deforestation as compared to reduced degradation and forest enhancement, we do not believe that the separation of rewards would discourage governments from promoting reduced deforestation, or that such separation would alter the overall REDD+ system. Rather, we consider that it would encourage participation by providing appropriate rewards for all the stakeholders involved.

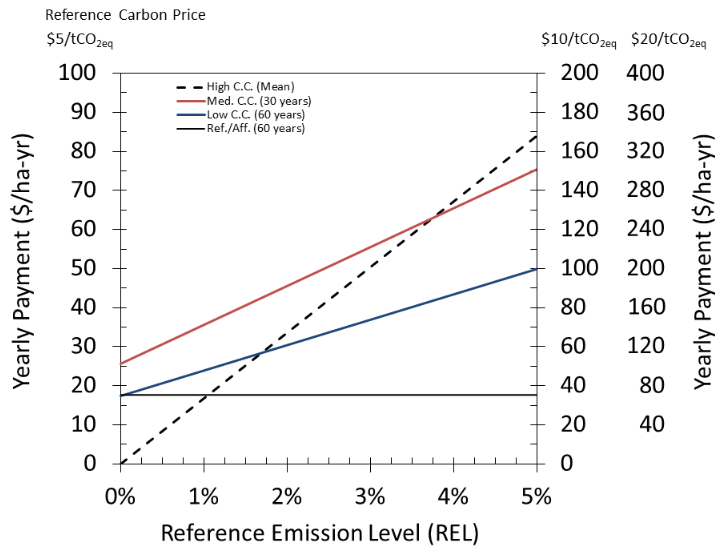
A formal registration of all activities under the national REDD+ program would be required to maintain a national registry of carbon credits generated and sold, and also to identify areas not voluntarily participating in REDD+ where land use regulations and control of illegal activities should be more stringent. We consider that finance for national policies implemented by the public sector as part of REDD+ should be derived from regular government budgets, a small share of the carbon revenues can be used to cover some of the transaction costs of the government, since in general it will be difficult to assess exactly how they impact on carbon stocks; this could also reduce the risk of government trying to commandeer carbon "credits" generated at the local level by communities and local land owners. While the proposal presented may represent a sound and practical approach to the problem of distribution of benefits of REDD+, it is not yet at all clear to what extent the financial value of the "credits" will be sufficient on its own to generate adequate incentives for the participation of landowners. Both the biophysical potential for carbon gains for a broad range of ecosystems (from tropical rainforests to dry forests) and the international financial value of carbon "credits" will affect this, but in all probability, the funds derived from such "credits" will need to be supplemented by other sources of finance in order to achieve the goals of REDD+.

9.8. Corollary I: Sharing the Benefits from the Valuation of Forest Carbon Services in La Primavera.

As mentioned in this chapter it will be easier, at least initially, to allocate gains from reduced emissions at a regional scale (rather than at the parcel level). Considering that the public sector would implement activities helping to reduce emissions thus a share of the carbon gains could be used to finance these activities. For instance in the case of La Primavera the costs of fire prevention and combat are covered by La Primavera's management office, Jalisco's Rural Development Office and CONAFOR. Although the government of Jalisco is responsible to provide financing for the operation of the executive office in the Biosphere Reserve, at the beginning of 2012 La Primavera had only 30% of the $1.48 million budget required for operation (Gamez, 2012). In contrast the combined cost of controlling the recent large fire in La Primavera last April 2012 was around $0.6 million which was spent in over a week (del Castillo, 2012b). Although the budget required for the operation of La Primavera office includes activities which are not related to climate change mitigation, if carbon revenues are to be generated it could be possible to reach an agreement between landowners, communities and the public organisms to decide how these benefits will be shared in order to undertake the appropriate preventive and control measures. As mentioned in the Corollary to Chapter 8 at a REL of 1.84% reduced emissions would account for 37% of potential forest carbon services. Moreover, the government of Jalisco already owns around 15% of La Primavera (CONANP, 2000); if this area is properly managed it could produce finance in part the operation of the Reserve. In this case potential for financing can consider implementation costs rather than the WTA of providers.

9.9. Corollary II: REL, Carbon Prices and Incentives

Figure 9.1. Yearly payments for forest carbon services for different areas as function of carbon price and REL.



This section reviews briefly the role that carbon prices and the REL play in the generation of incentives for forest carbon services. As discussed in Chapter 4, the REL critically defines the magnitude of reduced emissions from deforestation and forest degradation (and thus total carbon services); if this is not carefully set perverse incentives can be created. Based on the potential production of forest carbon services presented in Chapter 4 (Figure 4.3), Figure 9.1 presents the yearly payments per hectare considering three different carbon prices ($5, $10 and $20/t$CO_{2eq}$). The yearly payments per hectare are obtained by multiplying the carbon potential by each of the carbon prices; thus three vertical scales are shown. These values were chosen based on the range of prices in existing markets (4.92/tCO_{2eq}, Krukowska and Carr, 2011)), the financial requirements for climate change mitigation (20 to $25/t$CO_{2eq}$, UN, 2010) and the results from the choice experiments ($6.79, $15.67 up to $36.1/t$CO_{2eq}$ for the higher limit of 95% C.I., Chapters 6 and 7).

The values per ha per year can be compared with the WTA of providers to assess potential for participation (Chapter 8). For instance, if the WTA is equivalent to $150/ha-year, this would be generated in areas with high C.C. at a price of $10/t$CO_{2eq}$ and a REL around 4.5%, or by a price of $20/t$CO_{2eq}$ and a REL about 2.2%. Similar analysis can be made for degraded areas. For reforestation/afforestation activities the price required to reach this payment level would be close to $40/t$CO_{2eq}$. When other co-benefits can be offered to landowners for participation and these reduce the WTA (for instance down to $40/ha-yr), the carbon prices and/or REL can be lowered. Thus participation can be expected in all forested areas at $5/t$CO_{2eq}$ and RELs from 1.5% to 3.5%. If the price negotiated goes above $11/t$CO_{2eq}$ payments would suffice to implement reforestation/ afforestation activities. Payments at a carbon price of $20/t$CO_{2eq}$ would permit implementation in all areas at RELs below 0.75%.

Negotiations under REDD+ have focused on the rationale and processes to set the baselines for carbon accounting. However, this may be a difficult counterfactual process; moreover, it may rely on data of very different quality considering the different capacities of the countries to monitor forests in the context of REDD+ (e.g. Romijn et al., 2012). The risk is that if the baselines are not carefully crafted they can create perverse incentives. Figure 9.1 shows the importance of increasing valuation of the carbon services in order to promote participation even at low RELs. From the demand side, valuation of carbon services would be expressed in higher carbon prices; from the supply side, increasing the benefits that providers receive from participation, including local environmental services and other co-benefits (conditional to performance), would lower the costs. This can open room space for broader agreements promoting local development where the benefits stemming from REDD+ could be shared.

10. Conclusions

The main gaps in knowledge identified in Chapter 2 have been addressed in the research Chapters (4 to 9), whose findings help to answer the five research questions presented in Chapters 1. Below, these five questions are presented and answered using the main highlights from the research chapters.

10.1. What is the potential production of carbon services in forests?

Chapter 4 focused on the study of the provision of forest carbon services in La Primavera; for this, information from a local inventory was used in combination with cartography, satellite images, allometric equations and tree growth models. Results indicate there are significant differences in carbon stocks for areas with different levels of canopy cover (i.e. levels of degradation). In average carbon stocks and potential enhancements in La Primavera are 170 tCO_{2eq}/ha (160-180tCO_{2eq}/ha, 95% C.I.) and from 2.2 to 5.9 tCO_{2eq}/ha-yr respectively; these values are within the range provided by default IPCC values and national data once differences in allometric models are considered. La Primavera has been subjected to a process of degradation mainly associated to recurrent forest fires and land use change. The estimates of potential growth of existing trees and removals from reforestation/afforestation activities indicate that if processes of forest degradation and deforestation from land use change are halted, potential removals would be similar to existing stocks. In order to include the benefits from reduced emissions for the quantification of forest carbon services, it is necessary to select a value for the reference emissions level (REL); this is a critical issue under REDD+ because it will determine the level of carbon gains that could be granted to areas where carbon stocks are in equilibrium and no further enhancements are expected potentially creating a perverse incentive (provided they are under risk of deforestation or degradation). If the REL is set at a level of 1.84%, which might correspond to the municipalities where La Primavera is located, forest carbon services would be 204.7 $ktCO_{2eq}$/yr (164.4 – 246.0 $ktCO_{2eq}$/yr) (13% from reforestation/ afforestation; 52% from enhancement in forests; and 37% from reduced emissions); still these estimates can be refined with the use of satellite imagery with higher resolution, the inclusion of more carbon pools and local developmental needs. These aspects can be included for a second round of measurements ideally in 2014 to obtain local data on enhancements including other carbon pools. It will be very important to evaluate the potential for further enhancements in areas with high canopy cover. The analysis of the forest inventory data indicates that basal area can be used as proxy for carbon stocks in biomass with the potential to generate rapid estimates per hectare. Chapter 5 presented an alternative method based on the relationship between basal area and biomass and carbon from allometric equations that could help to reduce the cost of quantifying carbon services in forests. This type of approaches can reduce the measurement costs, which are an important transaction cost in the valuation of forest carbon services.

10.2. What is the willingness of landowners and communities to adopt practices to provide them?

Chapter 8 presents the result of a choice experiment evaluating the potential participation of landowners and communities in incentive-based programs for the provision of forest carbon services in the study area (La Primavera and its wildlife corridors). Results indicate that potential participation will be lower in the areas closest to the city of Guadalajara where land opportunity costs are highest; however, the prospects for implementation increase as the distance from the city increases. Priority areas for implementation include communal areas owned by ejidos and private forest-land distant from the city; there are positive views for developing reforestation/afforestation practices in some grassland and also for promotion of agroforestry practices. The potential for participation increases even more when additional non-cash incentives in the form of community services are offered to the potential providers. Landowners and communities would be willing to participate for payment levels ranging from $40 to $150/ha-yr, the range depending on the role that these additional, non-cash incentives play. Experience from the national PES program indicates that some providers will have a lower WTA since participation has been observed at levels of $22.2/ha-yr. If the additional non-cash incentives promoting local development are included, the financing requirements can be relaxed; this situation was observed in a practical implementation project in the study area briefly described in Appendix to Chapter 8. From the perspective of a carbon buyer only interested in climate change mitigation, offering non-cash co-benefits will make sense only if the cost of providing them are lower than the cash incentives that otherwise would have been paid to the providers. Nevertheless, evidence from existing international carbon markets indicates that there is a segment of carbon buyers willing to support and even pay a premium for CDM carbon credits generating additional benefits (e.g. sustainable development; premium from 5 to 20% for Gold Standard certified CERs) (Drupp, 2011); thus there is potential for the development of projects maximizing not only climate mitigation but other co-benefits even in the global market. The description of the project implemented as a direct result of the research (presented in Appendix to Chapter 8) clearly demonstrates the importance of non-cash incentives targeting local development in the successful design of an offset project, and also illustrates how negotiation for such a project takes place between users and providers at the local level.

10.3. What is the valuation of citizens as users of forest carbon services and potential for participation in market-based mechanisms?

Chapters 6 and 7 present the results of the choice experiments used to assess the potential demand for forest carbon services in Guadalajara, Jalisco and other regions of México. The survey carried out permitted to contrast the differences in the valuation of forest carbon services in the context of local markets. Results indicate that environmental valuation expressed in implicit carbon prices increase when the option to buy offsets from local projects was offered. The range of carbon prices respondents were willing to pay is similar to that pertaining to existing compliance and voluntary markets, that is, from $4 to around $25/t$CO_{2eq}$. This is because projects in forests closer to potential buyers generate other co-benefits that are valued by buyers, including air quality, potential for recreation, landscape and water services. The selection of local options was also driven by a sense of local/cultural identity. In agreement with research elsewhere (e.g. Brouwer et al., 2010), these results indicate that valuation is stronger when projects are within the state of residence of the purchaser, particularly within the radius of 100 to 200 km from the city of residence of the participant. Chapter 6 shows that specific characteristics of the buyers (i.e. higher income and previous knowledge of emissions) are positively correlated with higher levels of valuation of forest offsets; one important condition for valuation is the acceptance of responsibility for personal emissions, this was also observed in results presented in Chapter 7. Results indicate that an important proportion of the participants in the experiment would be ready to participate in market-based mechanisms. From the demand side in Guadalajara around 80% of the respondents indicated they probably/certainly would participate if the project became operational.

10.4. What is the potential for a local market for forests carbon services and how these could interplay with international efforts to mitigate climate change (e.g. global carbon markets, REDD+)?

The yearly payments for forest carbon services (WTP), obtained considering the carbon prices for local projects and the potential forest carbon services in La Primavera, are higher than the WTA figures presented in Chapter 8 and the payment offered in the national PES program (Corollary in Chapter 8); this indicates that a local market mechanism is feasible. Prospects augment if buyers with higher income are engaged in trading and non-cash co-benefits are offered to providers. These results indicate that there will be a space for negotiations of agreements if the institutional framework for local markets is created. The scale of the forest carbon services provided by La Primavera served to identify the minimum level of participation required in comparison to the whole population of Guadalajara to fully value these services in a local market (Corollary Chapter 7). This comparison based on emissions per capita indicate that the participation required will be below 1% of the population of the city; if required demand is portrayed as the number of big companies needed only about a dozen will be necessary (although specific studies need to be developed as potential corporate participation was not part of this research). The responses to the choice experiments, presented in Chapters 6, 7 and 8 indicate positive prospects for development of a local market mechanism for forest carbon services. From the supply side, although there is lower potential for participation in the closest area to the city, opportunity costs may rapidly decrease with distance thus increasing potential participation; it would be necessary to reinforce land use change control in the vicinity of the city. It would be possible to design different strategies and policies for the implementation of activities in different areas (i.e. common areas in ejidos, private forests, grassland and agroforestry).

Based on the discussion presented in Chapter 9, it will be necessary to decide how the benefits from the valuation of forest carbon services will be shared locally. This is particularly important for the case of reduced emissions from deforestation and forest degradation (e.g. forest fires). As mentioned before the amount of reduced emissions would depend on the level of the REL.

Since the public sector covers a large amount of costs related to fire prevention and control, it will be necessary that if these services are to be valued an agreement is made among the different stakeholders to define how benefits will be shared (Corollary I to Chapter 9). However, as shown by results, up to two thirds of the total carbon benefits, at a REL of 1.84%, will stem from carbon removals (enhancement and sequestration); it will be easier to attribute these carbon gains at the parcel level and value them through private market mechanisms. These figures also show the potential perverse incentives that can be generated under REDD+ since incentives could be higher for areas which were previously degraded/deforested than those well preserved. If the level at which the REL is to be fixed ‘cannot prevent’ the generation of perverse incentives, then additional financing or controls should be in place; additional financing could come from local PES programs, or market-based mechanisms where financing is bargained directly by providers and users. Corollary II in Chapter 9 shows that increasing the valuation of forest carbon services would increase the feasibility of implementation under REDD+ even at low RELs. Perverse incentives could also be addressed through the valuation of another REDD+ element: the conservation of carbon stocks in forests. This can be estimated considering the difference in the incentives for areas in equilibrium and those for degraded/deforested areas receiving higher incentives at a given REL. However, if perverse incentives cannot be prevented this will show serious flaws of the institutional framework to account and value forest carbon services. In this context it will be easier to ‘fix’ these flaws by including the appropriate measures in the design of the local institutional framework for the valuation of forest carbon services in order to prevent the generation of wrong incentives in a context already surrounded by different public and market failures (as described in Chapter 2). Nevertheless, México would have to analyse carefully the convenience of participating in international carbon markets to sell the carbon credits abroad, since as discussed in Chapter 2, this could increase the cost of mitigation for local actors under the light of new local climate legislation.

10.5. What would be the potential contribution of these local mechanisms for development and what would be the implications for local climate policy?

Results presented in Chapter 8 indicate that landowners and communities would value non-cash incentives included in programs for the valuation of forest services. The implementation project described in the Appendix to the same chapter, confirms this result, and also shows that it is also possible for users of environmental services to consider the provision of these non-cash co-benefits as part of these negotiations. The creation of local market mechanisms can use the valuation of forest carbon services to engage actors in deeper negotiations, alliances and agreements including more than just the valuation of natural capital and cash payments. Alliances among specific public and private actors can help to raise additional financing, but most importantly can help providing specific non-cash incentives. It is necessary to create accessible and flexible options for participation, within an institutional framework, to capitalize the potential for local market mechanisms. The experience of the implementation project described in Appendix to Chapter 8, shows how local users and providers can meet and negotiate agreements for the provision of environmental services and how the inclusion of local co-benefits promoting local development motivated participation. The NGO knew that it had the option to buy offsets from distant projects at lower cost, but preferred a local project instead; it had the option to negotiate with an individual landowner and reduce transaction costs (e.g. coordination and negotiation) but decided instead to maximize social benefits by collaborating with a community. From the supply side it was the inclusion of these non-cash incentives that raised the ejido's willingness to participate and it is what has granted long term collaboration; though performance in implementation still needs to be monitored. The implementation project also shows the importance of the availability of information for the provision of environmental services; carbon accounting was used as a benchmark to define the scale for implementation for both, the demand side (i.e. by accounting for the carbon footprint) and the supply side (i.e. by identifying the potential for carbon sequestration in this region). It is important to point out that although the property rights over the environmental services/damages were not clearly established in the law (i.e. equivalent to the Law of Torts), both the providers and the users/buyers shared a framework of environmental responsibility. In practice, this set a common ground as regards the distribution of environmental property rights; this is what allowed them to engage in bargaining and reaching an agreement. It is not a minor implication for local policy since it stresses the importance of generating clear and accessible information on the potential provision, and use of environmental services. This information can include for instance the identification of the management practices and associated impacts in the provision of forests services in different areas; the preparation of inventories of GHG emissions or carbon footprint exercises; and the creation of networks of users and providers of environmental services which can reduce the costs of looking for partners to trade with.

From a more general perspective, results have other implications for climate policy. The relatively low levels of buyer participation that would be required to finance improved carbon management in La Primavera are positive in the sense that this indicates that task would be relatively easy, provided an institutional framework for a local market is created. On the other hand, it also shows that La Primavera could not possibly absorb all Guadalajara's GHG emissions. It is important to stress that in order to achieve local carbon neutrality the forest area required for offsetting would be much larger than La Primavera and/or that significant reduction in local emissions should take place. However, this implies that if the property rights over the environmental services are assigned to providers and the responsibilities on emissions are created among users as a means to reach a balance between emissions and removals by forests, there would not be a shortage of resources to finance climate change mitigation activities in forests. It may be possible that the sole generation of the information on provision and use of environmental services/emissions will suffice to engage the required number of actors to realise the value of a local market; as it has been described elsewhere, incomplete information may be at the base of transaction costs impeding trading to reach more socially desirable scenarios and producing the externalities (e.g. Dahlman, 1979; Zerbe and McCurdy, 1999).

10.6. Principal Research Question: What is the potential for local carbon markets targeting forest carbon services in developing countries?

The insights generated in the study of these research questions can be used to provide at least a partial answer to the main research question. The results obtained in this research indicate that local market mechanisms for forest carbon services in developing countries may indeed be feasible. By combining the data on the potential production of forest carbon services in oak-pine forests with the valuation of forest carbon services it was possible to estimate the WTP for forest carbon services. When these figures are compared with the local WTA figures and the data on potential implementation, in general the WTP is larger than the WTA. There are better prospects for the development of these activities in areas with lower opportunity costs; while the valuation of local co-benefits of forests are highest in areas closer to population centers the opportunity costs will also be high. It is clear that effective land use governance and enforcement of regulations are important preconditions for the development of such incentive-based schemes. Though these results were obtained from a single case study, they are intuitively logical and therefore it may be considered that they could be generalized to other cases in developing countries. In fact local markets can provide effective means to reduce mitigation costs to local actors; this is particularly important considering the domestic differences in the distribution of income and consumption (an then in emissions) (e.g. Feng et al., 2009; Balderas Torres et al., 2010b; Ananthapadmanabhan et al., 2007). The role that the forestry sector can play in mitigation is limited in this particular case, since there is a high level of emissions from the city in comparison with the capacity of a relatively small area of forest; the balance may be different if the analysis is made at a different geographical scale (e.g. state level), in other locations and in other countries. However, the study does indicate in general that if bargaining between users and providers of forest carbon services is fostered to promote a sustainable balance for removals and emissions, there would not be a shortage of resources for the implementation of mitigation actions in the forest sector; moreover, this could provide an excuse to redefine the local agenda for development.

The following three sections briefly discuss the implications of these findings in the context of market theory and the use of market-based mechanisms in climate policy. Section 10.7 presents a summary of the differences between climate change mitigation through local and global carbon markets in terms of co-benefits, transactions costs, the interest of the regulator and potential demand; section 10.7.1 presents how the consideration of co-benefits and transaction cost can influence environmental valuation and the scale of climate change mitigation; section 10.7.2 presents the differences of implementing mitigation activities from the global to local scales in comparison to a local to global implementation.

10.7. Co-Benefits and Transaction Costs in Local and Global Market Mechanisms

As mentioned throughout different parts of this research, the valuation of co-benefits plays an important role in the selection of mitigation actions and policy design. This can have important implications in the design of market mechanisms based on local demand. In Chapter 2 it was mentioned that transaction costs can facilitate or prevent the implementation of certain activities; these determine not only the potential for successful implementation, but in the broader sense only the institutions and institutional frameworks reducing the transaction costs will endure (North, 1990). Table 10.1 presents a summary of the expected differences in global and local market mechanisms for the mitigation of climate change in terms of: transaction costs, impact of co-benefits in valuation, the interest of the regulator and the potential demand.

Table 10.1 Comparison of global and local market mechanisms in terms of effect on transaction costs, effect of co-benefits, the interest of policy-makers and potential demand.

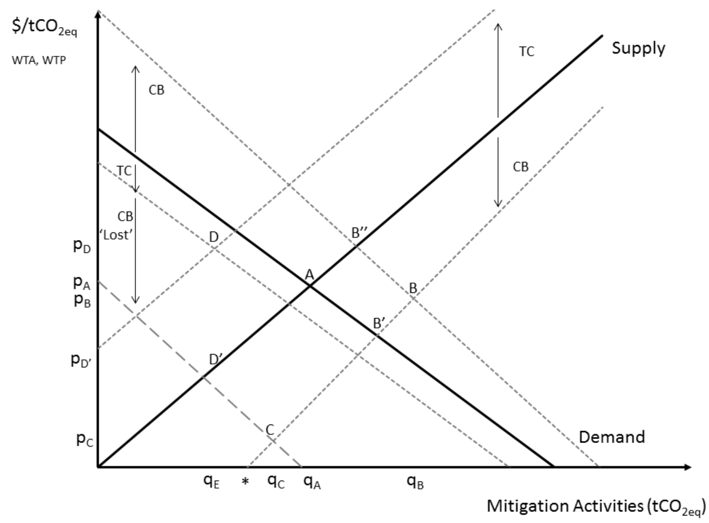
	Non-Local Action (Global Market)	Local Action (Local Market)
Transaction Costs		
Definition of institutional framework shaping property rights	(+) Cost of international negotiations, difficulties to reach consensus. Slower implementation.	(-) Relatively faster design and implementation by local governments (e.g. Law on Climate Change in México).
Search of a partner to trade with, communication, negotiation costs.	(+) Travel costs; impersonal communication, reliance on intermediaries; language barriers.	(-) Possibility for personal communication; easier to increase trust.
Commissions by intermediaries and brokers	(+) Higher commissions; speculation can capture consumer's surplus.	(-) Lower need for brokers, providers and users can meet personally.
Enforcement of contracts	(+) Need to consider international legal/ institutional framework and that of countries involved; potential misfits. Difficulties to enforce non-compliance with international agreements.	(-) Agreements under a unique framework; lower litigation costs. Easier to enforce contracts under a unique framework.
Monitoring	(+) Higher difficulties for buyers to verify directly the outcomes of the projects.	(-) Buyers can verify directly the progress and outcome of the projects reducing the cost; cheaper local monitoring.
Certification	(+) Higher dependency on costlier certification processes to back-up project's outcome (i.e. international travel).	(-) Direct verification by buyers; cheaper to develop local certification standards.
Co-Benefits		
Local-Direct	(-) None.	(+) Highly valued: air quality, local climate, water, health, recreation, landscape, etc.
Local-Indirect (regional/cultural identity)	(-) Lower, contingent to personal background.	(+) Higher within the barriers same geopolitical jurisdictions of buyers.
Other Non-Local (Social Development/ Biodiversity).	(+) Global co-benefits can increase valuation.	(=)(+) If these can be generated locally, local options would be preferred.
Interest of Policy-Makers.	Reduce the mitigation cost.	Maximize local welfare (co-benefits) and minimize mitigation cost for local actors.
Potential Demand	Potentially more buyers; conditioned by institutional framework of each country.	Local demand can be stimulated detached from international negotiations.

The comparison made in Table 10.1 assumes that mitigation options can already be implemented in different countries, including the country where the buyers are located; it assumes that the two markets exist. The inclusion of co-benefits is more likely to promote local action rather than a large international coalition (e.g. under the UNFCCC) (Finus and Rubbelke, 2008). In general, local markets will have lower transaction costs and higher co-benefits than global markets. The design and agreement for the institutional framework and definition of property rights can be more easily arranged for a local market; pressure by a better informed and aware society which values the benefits of climate change mitigation and adaptation can contribute to this process. At the local level the consideration of co-benefits and economic savings can promote the adoption of climate policy (Kousky and Schneider, 2003); these two factors may tip the balance in favour of local markets from the regulator's perspective. Transaction costs can be reduced in local markets in a variety of ways: the possibility that buyers and providers can meet personally can build trust; trust can substitute contracts, lowering transaction costs and increasing the flexibility of the schemes (Arrow, 1971; Beugeldsijk and van Schaik, 2001). This can also decrease the dependency on external brokers/intermediaries thus reducing speculation and additional transaction costs resulting in more efficient schemes. Providers and users can have greater control of market development, increasing competition; although actors will still require third parties as consultants, certifiers or as means to consolidate demand and supply. Local markets can include local monitoring and certification standards which can reduce the cost further (e.g. community monitoring of forestry carbon projects, Skutsch (2011)). The possibility for buyers to visit project areas and verify the outcomes themselves can help to overcome the principal-agent problem, which is a serious impediment in international markets (Murray and Dey, 2009; Spash, 2010); this can help to increase the transparency of the scheme and the outcomes of the implementation.

Local markets can help to maximize local welfare through the generation of a wide range of local co-benefits in the present (e.g. Pearce, 2000). They can also produce local indirect co-benefits such as regional or cultural identification. Including other co-benefits in mitigation projects in the global market does increase valuation (Drupp, 2011). However, when this type of co-benefits can also be generated locally, then the valuation of other local direct benefits can drive the preference for local options (e.g. biodiversity services, Garrod et al., 2012). For instance if there is rural poverty in the region where buyers are located, it could be more sensible for them to channel resources locally to mitigate climate change and alleviate poverty than to recur to global markets; this can also have additional co-benefits as reduction of unemployment, crime or migration. Although potentially there could be more offset buyers in the global market, this depends on the institutional framework constructed in each country.

10.7.1. Transaction Costs and Co-Benefits in the Demand-Supply Diagram

Figure 10.1 Supply and demand diagram including the effect of co-benefits (CB) and transaction costs (TC).



The approach used by Pearce (2000) to evaluate the effect of the co-benefits for the identification of no-regret targets in cost-benefit analysis of climate policy is used to identify the effect that transaction costs and co-benefits can exert on the carbon price and level of mitigation in market-based mechanisms. Figure 10.1 presents a modified version of the demand-supply diagram presented in Chapter 1 (Figure 1.1) accounting now for the effect of transaction costs (TC) and co-benefits (CB) for both providers and buyers.

In Figure 10.1 the point A (at p_A and q_A) presents the baseline; this point is considered as reference to contrast different scenarios. It can be observed that *ceteris paribus* a scheme generating higher transaction costs would reduce the resources available for mitigation (demand) and would increase the provision costs (supply) (Point D); conversely when co-benefits are generated these would increase the WTP (demand) and would reduce the provision costs (supply) (point B); in global carbon markets, when buyers consider the forgone co-benefits as the cost of the 'missed opportunities' to increase the local welfare, the WTP will fall further (CB ‘Lost’) (e.g. point C).

The maximum level of mitigation q_B will be achieved in B when both producers and buyers consider co-benefits for participation. The cost of mitigation or the carbon price in B can be higher, lower or equal than the reference cost p_A depending on the relative value of co-benefits for the supply and demand (vertical range from B’ to B’’). This portrays the case of local markets where buyers and producers maximize co-benefits and reduce transaction costs. Point C shows the case of the global markets when buyers consider distant offsetting as cost and where producers still access co-benefits. The price paid to providers will reduce to p_C. It can be noticed that if co-benefits for producers are significantly large the activity itself can become a no-regret action as defined by Pearce (2000) with ‘negative cost’ for the providers. Producers could implement mitigation activities from zero up to the point (*) as long as they access the co-benefits. This also indicates that once the project costs have been covered, potential gains from carbon trading could be easily captured by intermediaries since the sole operation of the project would suffice to produce the co-benefits and grant participation. Point D shows the alternative scenario where there are no co-benefits for providers or users but instead there are higher transaction costs. In this case the buyer will be paying p_D but the producer will be receiving a real payment for implementation of $p_{D'}$. The difference between the WTP and $p_{D'}$ are the inefficiencies of the market due to transaction costs.

10.7.2. Mitigation: Local to Global or Global to Local?

An interesting conclusion can be made as regards the order of implementation of mitigation activities. Usually supply-demand diagrams relate decreasing demand with increasing supply costs. However, as shown here both the valuation (WTP) and potential provision and WTA can vary geographically. Using information derived from this research, Figure 10.2 presents the comparison of WTA and WTP for forest carbon services for the two scenarios (i.e. global leading to local or local building up to global).

Figure 10.2a presents the standard comparison between supply and demand presenting WTP decreasing in contrast with an ascending WTA; in this case it represents implementation starting from non-local actions and moving to local markets at the end. Conversely Figure 10.2b presents the curves for WTP and WTA with activities first implemented in a local market and then in a global one[25]. The WTP curve is derived from the average potential of forest carbon services in La Primavera to convert the valuation in terms of carbon prices to payment per hectare per year for the WTP curve.

Figure 10.2 Differences in the implementation market-based mechanisms comparing an implementation going from Global to Local (a) and Local to Global (b).

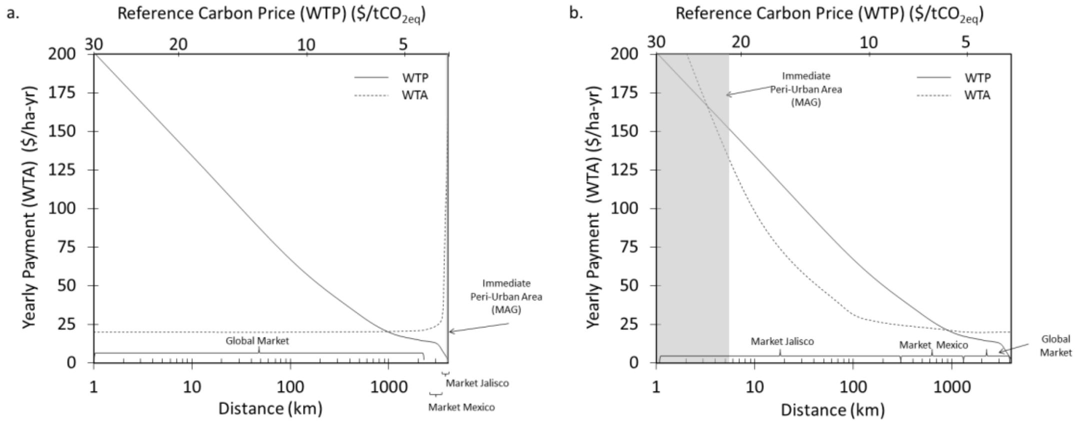


Figure 10.2a indicates that if buyers only want to minimize cost/expenditure, those with highest WTP will first buy the options offering the lowest price in international markets. As the mitigation cost increases the equilibrium between demand and supply will be reached, preventing some buyers with lower WTP from buying offsets (as the cheapest options would have already been taken). The diagram implies that buyers in Guadalajara will not buy local offsets (since the highest opportunity and implementation costs may be in the peri-urban area where landowners are less keen to participate). Standard welfare measures would indicate that buyers maximize consumer surplus (the area between the WTP and the WTA (price) curves, until the point at which they reach the equilibrium); however, this may be an overestimation since higher WTP is associated with access to local co-benefits and these contribute to local welfare and activities closest to Guadalajara would not be implemented.

Figure 3b presents both the WTP and WTA decreasing as a function of the distance to Guadalajara showing the implementation from the local to the global scales. The WTA is presented as follows: for the area closest to Guadalajara it is set above the WTP, given the lower prospects of participation due to high opportunity costs; however, potential for participation increases rapidly with distance; thus WTA it is held below the WTP until it matches the payment level set by the national PES program. This cost is held constant and represents the WTA for the provision of these services in other parts of México. The WTA in the global market is slightly reduced, given the lower carbon price (<\$5/tCO$_{2eq}$). In this case, buyers with highest WTP could finance activities with higher provision cost in areas close to the city, increasing local co-benefits and welfare. In the peri-urban area (in grey), improved land use regulations will be fundamental to ensure the provision of the environmental services. Going

[25] The limits of the markets on the horizontal axis are included as indicative reference only; however, in order to forecast if demand would or would not be enough to buy in a local/global market the actual potential over the whole region (Jalisco and Mexico) needs to be modeled in terms of provision, supply and demand. Nevertheless, the geographical scale the horizontal axis in Figure 10.2 presents the general trend in valuation considering the geographical variation.

from local to global also may enable groups with lower WTP to participate by buying cheaper offsets until supply matches again the demand. The gradual implementation from the local to the global scale will generate a positive financial externality for the areas with lower mitigation costs. As the initial carbon price would be higher, it will create an initial reference for the value of the carbon services which will help providers in more marginal areas to negotiate higher carbon prices; this is important considering that usually the lower WTA and opportunity costs in marginal areas are correlated with poverty (Martinez Alier, 2004).

One important remark is that local markets portrayed in this way will have lower available margins to cover transaction costs (the difference between WTP and WTA), indicating the need for an appropriate institutional framework lowering transaction costs as far as possible. Conversely, the situation described in Figure 10.2a, which is more similar to how global markets work, indicates that these can afford to cover high transaction costs and still engage some providers and buyers, given the wide differences in WTP and WTA.

10.8. Final Remarks

10.8.1. Implications for Local Policy

In the previous section specific implications for climate policy were made in terms of potential contribution to development and to the balance between emissions and removals. These closing sections remark specific aspects that can be incorporated into the design of the institutional framework for local mechanisms for forest carbon services.

As explained in Chapter 2, an integral strategy to value forest carbon services should not only include market-based schemes, but also measures to address the problem of externalities and other public and market failures related to the valuation of forest services. Ideally a diagnosis of the causes and solutions to deforestation and forest degradation as the described in Chapter 2 would help to identify the best strategies at the local level (e.g. municipalities, ejidos). Based on these initial studies different options to address the relevant public and market failures can be identified. Some of the solutions that present themselves include: definition of forest management options and costs and benefits of the provision of the environmental services (to overcome problems related to incomplete information); review of the existent regulatory framework and evaluation of compliance (to identify public failure, and define property rights); improving access/adoption of sustainable management certification schemes and linkage with markets (to lower transaction costs and costs of searching for partners to trade with); preparation of development plans and strategies increasing off-land income (reduction of dependency on land-based income/opportunity cost); definition of property rights over environmental services and responsibility on environmental damages; and preparation of public information to enable participation in market-based mechanisms (i.e. information on baselines, potential carbon gains of different management practices, methods for monitoring, promotion of local demand) (to lower transaction costs, of generation of information and search of partners to trade with).

Depending on the findings of these diagnoses, different policy options may be developed to play different roles. As discussed in Chapter 2, there will be cases where market-based mechanisms will represent good options to provide incentives to landowners/communities (e.g. conservation and areas with little economic yield from timber extraction). Figure 10.3 shows how these incentive-based programs could be integrated at the local level; it presents

Figure 10.3 Diversity of land-uses and income sources for landowners and communities showing the potential insertion of PES, carbon markets and REDD+.

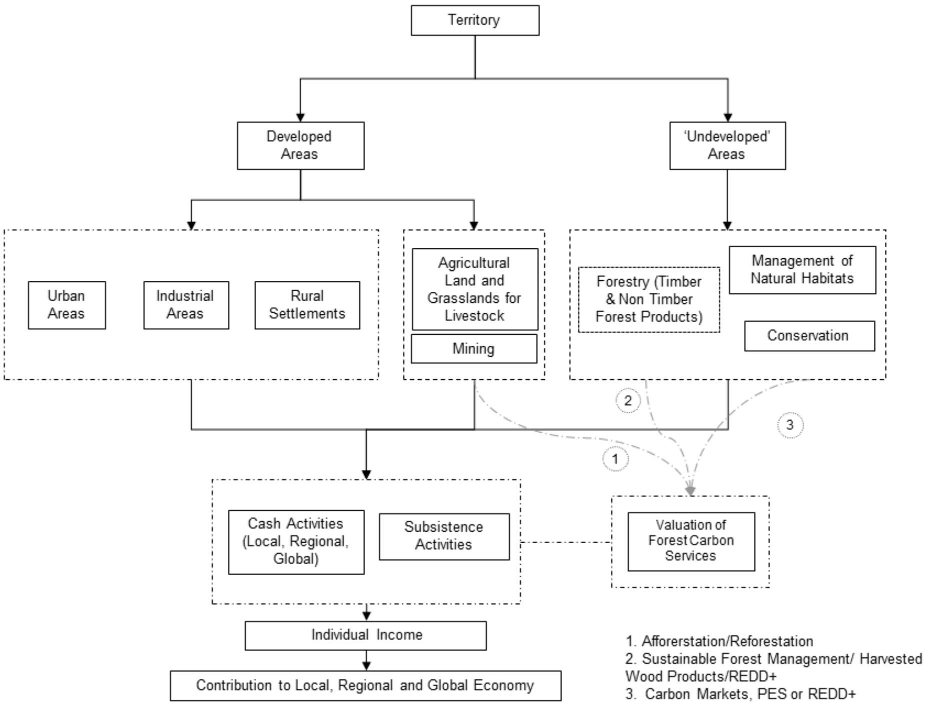


Figure 10.3 presents a simplified division of the different land uses in a given territory. The transition from a natural habitat to other land uses can be product of a one-step direct deforestation or a continued degradation of forests. New land uses may be adopted to attend subsistence, local or global needs expressed through the markets for different goods and services. It is in these converted areas where the productive activities are usually developed, contributing to private and individual income and aggregating into the local regional and global economy. During the transition of a parcel of land from natural to 'developed' status, timber and non-timber forest products (NTFP) can be used in a sustained way (commercial forestry) or in a one-time shot fashion when deforestation occurs.

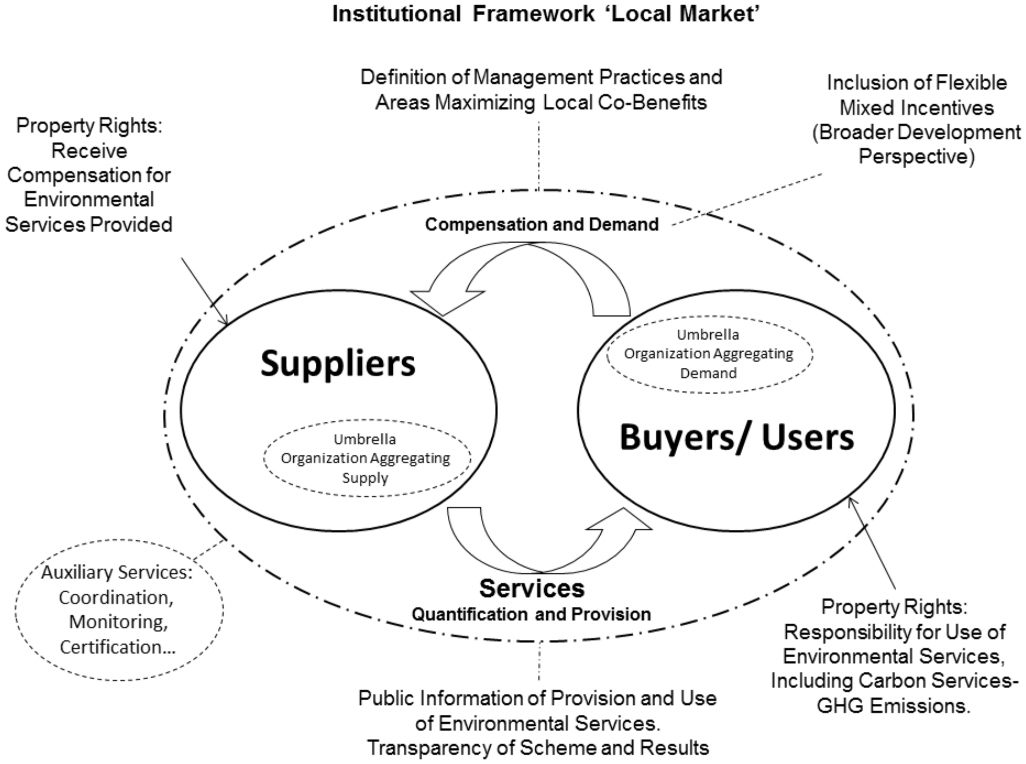
It is important to point out that the institutions, infrastructure and services across the territory enable landholders to develop different productive activities to different extents. Special attention should be paid to the institutional frameworks shaping land tenure and land use regulations since these define how land and natural resources are endowed to members of the society and how they are transferred in the markets. These institutions and frameworks also entitle the landholder to develop certain productive activities, thus contributing to the definition of the actual property rights over the environmental services; this also affects the potential participation in incentive-based activities (e.g. Markowski-Lindsay et al., 2011). These two factors, endowments and entitlements, define from a legal point of view what activities can be carried out, where they can be done and by whom. The endowment of a resource defines the property rights or access to it (in this case land or forests), on the other hand the entitlement enables or restricts the potential to benefit from them (Wiersum and Arts, 2009). The infrastructure and services present in a given area also induce the development of certain activities by determining different requirements of investment/effort to perform them (technology, capital and/or labor). The ideal scenario would be that when the potential land uses and their social, economic, environmental and distributional aspects have been evaluated in order to design and implement successfully local land use regulations. However, even if these regulations are defined, they may not be actually followed; there is widespread occurrence of failures in the regard. The real land use assemblage of a territory may represent or not what was intended by policymakers in regulations. The distribution of land and access to resources is also a consequence of cultural, social, economic and historical processes. These processes shape the development, economic wealth and distribution of benefits in a society. The situation often observed is that rural areas are poorer and with reduced access to services and infrastructure in comparison with developed urban areas, and this is especially the case in developing countries.

In this context, market-based mechanisms and incentive programs aiming at maintaining and enhancing the provision of environmental services, particularly carbon services, can be devised to target specific activities in specific areas. Figure 10.3 presents a scheme of the specific areas where incentives for the valuation of forest carbon services could be included as part of a local policy mix. For instance afforestation and reforestation activities can be implemented in areas that are currently not forests (i.e. cropland, grasslands and mining areas); these activities can receive financing from existing carbon markets. On the other hand REDD+ and PES activities focus on forestland. Depending on the specific activities to be developed, different solutions and incentives can be devised including market mechanisms. These policies can co-exist with other efforts to address public and market failures. In developed areas, another set of policies would have to be designed and implemented with a larger focus in the reduction of GHG emissions. Results show that it is possible to target local demand for forest carbon services to generate adequate levels of financing.

10.8.2. Closing Comments

In the compliance global carbon market as initially set up under the Kyoto Protocol there were two well defined groups of countries: the ‘buyers’ (those listed in Annex B) and the ‘providers’ (non-Annex B). Under this scenario it made sense for developing countries to trade offsets produced in their territories and for developed countries to buy them. This classification has been broken due to the difficulties in the negotiation of more ambitious legally binding emission reduction commitments and the need to engage non-Annex I with high level of GHG emissions into mitigation efforts. The low emission reduction target and high uncertainty with regards the future of the scheme under Kyoto Protocol produced a reduction of the demand for carbon credits from the global market among developed countries. In this context many developing countries, particularly emerging economies have started to develop their own climate mitigation strategies, including market mechanisms and internal emissions reduction targets. Hence these countries need to think about the best way to achieve these targets and to start to look themselves not only as providers of cheaper offsets but also as potential buyers; they would also need to look at the implications that the participation in such global market mechanisms may have for domestic providers and users.

Figure 10.4. Suggestions for the design of an institutional framework for local market mechanisms valuing forest carbon services.



Information is an essential input for the design of climate policy. Many non-Annex I countries still have limited information for decision making. México, which is the non-Annex I country most experienced in the elaboration of GHG inventories and national communications to the UNFCCC, was one of the first countries to set a voluntary emissions reduction target back in 2008 and has now passed a specific legislation on climate change. As the learning curve in the generation of this type of information progresses, more countries will start to identify their priorities in relation to local climate policies, and in this context local co-benefits will play a major role. As results of this research show, local market mechanisms for forest carbon services may not only be feasible but in fact have the potential to reduce the transaction costs and increase the valuation of these services when compared with the global market. Figure 10.4 presents the key inputs for the design of the institutional framework for local market mechanisms based on the research findings.

Results show that the development of forestry-based mitigation actions closer to potential offset buyers generates higher valuation and co-benefits. The institutional framework for local market mechanisms can define the management practices and areas where activities maximizing local co-benefits can be implemented. Bargaining between suppliers and buyers/users will be enhanced if the property rights over the environmental services, and the responsibility for their use, are better defined as part of the institutional framework. The inclusion of flexible mechanisms enabling the use of mixed incentives as part of this bargaining process (e.g. non-cash compensation) can help to engage providers and reduce the mitigation costs; moreover, this can contribute to create new alliances among different actors, fortifying social capital.

Interestingly, generating the information of the provision and use of the environmental services can help to mobilize actors sharing a common view over environmental property rights (i.e. environmental responsibility); this can be helpful during early stages of implementation of local market mechanisms considering that it could be difficult to create formal accountability over GHG emissions. From the supply side information demonstrating the potential for the production of forest services can encourage landowners and communities to find partners to trade with, while framing a clear scope for implementation (i.e. it would be possible to identify the number of buyers needed considering the capacity to produce the services). From the demand side promoting in citizens a better knowledge of their use of the environmental services (e.g. carbon footprint or GHG emissions inventories) and their responsibility for these, along with the information on options for dealing with them can help to promote action (i.e. by identifying how many tonnes or hectares of forest are required to neutralise carbon emissions). By entitling the producers to the right to get benefits from the finite amount of environmental services that can be produced (e.g. carbon offsets), the coordination costs of the system could be reduced in comparison with other schemes aiming to engage individual action as personal carbon trading (i.e. it will not be necessary to monitor the cap for all the individuals).

Reliable information related to the provision, use, management practices and eligible areas can substantially reduce transaction costs and identify alternative scenarios for implementation. It would also be very important that schemes are transparent and produce clear assessments of the outcomes of the activities implemented, otherwise if buyers perceive there is corruption or actions are ineffective demand would diminish. If there are more incentives for suppliers and buyers to bargain directly, the role of brokers or intermediaries should be reduced (e.g. large suppliers and buyers will have their own 'carbon' or 'climate' units); the institutional framework can include specific tasks for third parties focused on monitoring and certification of the projects/activities. In order to create economies of scale and coordinate the actions of suppliers and/or users, a third party organisation can help to reduce some coordination costs by aggregating demand and/or supply as usually occurs in PES programs and the voluntary market. However, in order to achieve efficiency in market mechanisms this coordinating organisation would have to reduce transaction costs and be flexible in terms of price setting and the type of incentives that can be included in the agreements. Thus this organisation could be a decentralised government agency or an *ad hoc* non-profit private actor hired, or created, by the suppliers or users.

One of the problems often arising from the provision of public goods is free-riding (e.g. Wohar, 1988); this refers to the problem of excluding those who are not contributing to the provision of the public good from enjoying the associated benefits. However, as shown by the case of La Primavera, it is not necessary that 100% of the population participate in the provision of the public goods. The provision of climatic public benefits and other local co-benefits will be realised if an equivalent to less than of 1% of the population of Guadalajara participates in valuing carbon services in La Primavera. In order to motivate this, the institutional framework could create some rivalry or competition provided that the compensation for the environmental services provided by La Primavera is adopted as a goal under the local policy framework (i.e. incentives to create a sense of competition to acquire the limited offsets that can be produced locally). Prospects of implementation can be improved further if the scheme promotes cooperation, solidarity and subsidiarity among the relatively few actors required, since it is the participation of few actors required what would generate benefits for all. From this perspective the quantification of forest carbon services and related emissions in tonnes of carbon can function as an auxiliary indicator to determine the size of individual contributions necessary to mitigate climate change for both users and providers, and also as an excuse to engage different social actors in broader negotiations and alliances promoting local development. Once market-based mechanisms are consolidated in the areas where they prove to be the best policy option, and PES is decentralized, the government's role could focus on the regulation and monitoring of the market, allowing local actors to organise the supply and demand for environmental services between them.

References

Abildtrup, J., Garcia, S., Boye Olsen, S. and Stenger, A. (2011). *Spatial preference heterogeneity in forest recreation*. Paper prepared for presentation at the EAAE 2011 Congress Change and Uncertainty. August 30 to September 2, ETH Zürich, Switzerland.

Achtnicht, M. (2011). Do environmental benefits matter? Evidence from choice experiments among house owners in Germany. *Ecological Economics*, 70, pp. 2191-2200.

Adam, D. (2008). *México leads the way with carbon reduction pledge*. The Guardian, disponible en linea: http://www.guardian.co.uk/environment/2008/dec/11/poznan-climate-change-México-carbon-pledge, disponible al 2 de Junio de 2012.

Adaman, F. et al., (2011). What determines urban households' willingness to pay for CO2 emission reductions in Turkey: a contingent valuation survey. *Energy Policy*, 39, pp. 689-698.

Akter, S. and Bennett, J. (2009). Household Perceptions of Climate Change and Preferences for Mitigation Action: the Case of the Carbon Pollution Reduction Scheme in Australia. Prepared for: Australian Agricultural and Resource Economics Society: 53rd Annual Conference 2009

Akter, S., Brouwer, R., Brander, L. and Beukering, P. van (2009). Respondent uncertainty in a contingent market for carbon offsets. *Ecological Economics*, 68, pp. 1858-1863.

Alcocer, M. et al., (forthcoming). Programa Estatal de Accion Ante el Cambio Climatico del Estado de Jalisco. Inventario de Emisiones y Remociones de GEI en el sector de Agricultural, Bosques y Otros Usos de Suelo. Programa Estatal de Acción ante el Cambio Climático del Estado de Jalisco. (Mauricio Alcocer Ruthling, Coord.) Universidad Autónoma de Guadalajara, 2011-2012, México.

Aldy, J.E., Barret, S. and Stavins, R.N. (2003). Thirteen plus one: a comparison of global climate policy architectures. *Climate Policy*, 3 (4), pp. 373-397.

Alpizar, F., Carlsson, F. and Martinsson, P. (2001). Using choice experiments for non-market valuation. *Economic Issues*, 8, pp. 83-110.

Ananthapadmanabhan, G., Srinivas, K. and Gopal, V. (2007). *Hiding Behind the Poor*. Report by Greenpeace on Climate Injustice, New Delhi, India.

Angelsen, A. et al., (2009). *Realizing REDD: National Strategy and Policy Options*. Center for International Forestry, Bogor, Indonesia.

AP (2011). No todo es negro en México: Maná. Newspaper article, *El Siglo de Torreón*, 8th September 2011. Available on-line: http://www.elsiglodetorreon.com.mx/noticia/658540.no-todo-es-negro-en-México-mana.html, accessed on 12th August, 2012.

Araujo-Murakami, A., Arroyo-Padilla, L., Killeen, T.J. and Saldia-Paz, M. (2006). Dinámica del bosque, incorporación y almacenamiento de biomasa y carbono en el Parque Nacional Noel Kempff Mercado. *Ecología en Bolivia*, 41, pp. 24-45.

Arrow, K. (1971). Political and economic evaluation of social effects and externalities. In: M. Intriligator (Ed.), *Frontiers of qualitative economics*, pp. 3-25, Amsterdam: North-Holland.

Aukland, L., Moura Costa, P. and Brown, S. (2003). A conceptual framekwork and its application for addressing leakage: The case of avoided deforestation. *Climate Policy*, 3, pp. 123–136.

Baker, T.R., Phillips, O.L., Malhi, Y., Almeida, S., Arroyo, L., Fiore, A.D. et al., (2004). Increasing biomass in Amazonian forest plots. *Philosophical Transactions of The Royal Society Biological Sciences*, 359, pp. 353–365.

Balderas Torres, A. (2007). *Assessment of the importance and potential of carbon sequestration projects for climate change mitigation: How can afforestation and reforestation projects* *be attractive for landowners in marginal areas and be developed at lowest costs?* M.Sc. Dissertation. York, England: University of York.

Balderas Torres, A., Lovett, J.C. and Skutsch, M. (2009). Assessing the feasibility to link urban and rural areas through local markets for forest's carbon services and the potential for local development: a methodological proposal. *Proceedings of the XIII World Forestry Congress. Forest in Development a Vital Balance*. Buenos Aires, Argentina.

Balderas Torres, A., Marchant, R., Lovett, J.C., Smart, J.C.R. and Tipper, R. (2010a). Analysis of the carbon sequestration costs of afforestation and reforestation agroforestry practices and the use of cost curves to evaluate their potential for implementation of climate change mitigation. *Ecological Economics*, 69, pp. 469-477.

Balderas Torres A., Skutsch, M. and Lovett, J.C. (2010b). *Perfil General de Emisiones de Gases de Efecto Invernadero (GEI) de los hogares en México en el 2006*. Poster presented in II Simposio Internacional del Carbono en México. Programa Mexicano del Carbono, Instituto Tecnológico de Sonora, Instituto Nacional de Ecología 6 al 8 de Octubre 2010, San Carlos Nuevo Guaymas Sonora, México.

Balvanera, P. and Cotler, H. (2007). Acercamientos al estudio de los servicios ecosistémicos. Gaceta Ecológia. *SEMARNAT*, 84 (84), pp. 8-15.

Bamberg, S. and Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, 27, pp. 14-25.

Barnes, G. (2009). The evolution and resilience of community-based land tenure in México. *Land Use Policy*, 26, pp. 393-400.

Basnet, R. (2009). Carbon ownership in community managed forests. *Journal of Forest and Livelihood*, 8, pp. 77–83.

Bass, S. et al., (2000). *Rural Livelihoods and Carbon Management*. An Issues Paper. International Institute for Environment and Development, Forestry and Land Use, London, UK.

Bateman, I.J., Day, B.H., Georgiou, S. and Lake, I. (2006). The aggregation of environmental benefit values: welfare measures, distance decay and total WTP. *Ecological Economics*, 60 (2), pp. 450-460.

Bator, F.M. (1958). The anatomy of market failure. *The Quarterly Journal of Economics*, 72, pp. 351-379.

Baumgardner, D., Varela, S., Escobedo, F.J., Chacalo, A. and Ochoa, C. (2012). The role of a peri-urban forest on air quality improvement in the México City megalopolis. *Environmental Pollution*, 163, pp. 174-183.

Beerling, D.J. and Woodward, F.I. (2004). *Vegetation and terrestrial carbon cycle: modeling the first 400 million years*. Cambridge, United Kingdom: Cambridge University Press.

Beier, P. (1993). Determining Minimum Habitat Areas and Habitat Corridors for Cougars. *Conservation Biology*, 7(1), pp. 94-108

Ben-Akiva, M.E. and Lerman, S.R. (1985). *Discrete choice analysis: theory and application to travel demand*. Cambridge, USA: MIT Press.

Bennett J. and Adamowicz V. (2001). Ch 3. Some Fundamentals of Environmental Choice Modelling. In: Bennett, J. and Blamey, R. (Eds), *The choice modelling approach to environmental valuation*. Cheltenham, UK: Edward Elgar, pp. 37-69.

Bennett J. and Blamey, R. (2001). Introduction. In: Bennett J., Blamey R. (Eds), *The choice modelling approach to environmental valuation*. Cheltenham, UK: Edward Elgar, pp. 1-10.

Bennett, J. (2006). Choice modeling and the transfer of environmental values. In: Rolfe, J. and Bennett, J. (Eds), *Choice modelling and the transfer of environmental values*. Cheltenham, UK: Edward Elgar.

Bennett, J. and Adamowicz, V. (2001). Some fundamentals of environmental choice modelling. In: Bennett J. and Blamey R. (Eds), *The choice modelling approach to environmental valuation*. Cheltenham, UK: Edward Elgar, pp. 37-72.
Bergmann, A., Hanley, N. and Wright, R. (2006). Valuing the attributes of renewable energy investments. *Energy Policy*, 34, pp. 1004-1014.
Berk, R.A. and Fovell, R.G. (1999). Public Perceptions of Climate Change: A Willingness to Pay Assessment. *Climatic Change*, 41, pp. 413-446.
Berrens, R.P., Bohara, A.K., Jenkins-Smith, H.C., Silva, C.L. and Weimer, D.L. (2004). Information and effort in contingent valuation surveys: application to global climate change using national internet samples. *Journal of Environmental and Economics Management*, 47 (2), pp. 331-363.
Berumen (2005). Presentacion *Estudio de Opinion sobre el Bosque La Primavera*. Berumen y Asociados S.A. de C. V. Junio de 2005, México
Beugeldsijk, S. and Schaik, T. van (2001). *Social capital and regional eocnomic growth. Discussion*. Paper No. 2001-102. Tilburg University. ISSN 0924-7815, CentER.
Bi, H. et al., (2010). Additive prediction of aboveground biomass for Pinus radiata (D. Don) plantations. *Forest Ecology and Management*, 259, pp. 2301-2314.
Birol, E., Smale, M. and Gyovai, Á. (2006). Using a choice experiment to estimate farmers valuation of agrobiodiversity on Hungarian small farms. *Environmental and Resource Economics*, 34, pp. 439–469.
Black-Solís, J.D. (2003). *Diseño institucional y financiero de proyectos de captura de carbono atractivos para pequeñas plantaciones forestales*. Tesis sometida a consideración de la Escuela de Postgrado, Programa de Educación para el Desarrollo y la Conservación, del Centro Agronómico Tropical de Investigación y Enseñanza como requisito parcial para optar al grado de: Magíster Scientiae. Costa Rica.
Boyle, K.J. and Bergstrom, J.C. (1992). Benefit transfer studies: myths, pragmatism, and idealism. *Water Resources Research*, 28 (3), pp. 657-663.
Brainard, J.S., Bateman, I.J. and Lovett, A.A. (2009). The social value of carbon sequestered in Great Britain's woodlands. *Ecological Economics*, 68, pp. 1257-1267.
Brey, R., Riera, P. and Mogas, J. (2007). Estimation of forest values using choice modelling: An application to Spanish forests. *Ecological Economics*, 64 (2), pp. 305-312.
Broadbent, E.N. et al., (2008). Spatial partitioning of biomass and diversity in the lowland Bolivian forest: Linking field and remote sensing measurements. *Forest Ecology and Management*, 255, pp. 2602-2616.
Brockhaus, M. (2009). *Realising REDD+; National Strategy and Policy Options*. In: Angelsen, A. (Ed.), Bogor Barat, Indonesia: Center for International Forestry Research.
Brouwer, R., Brander, L. and Beukering, P. van (2008). A convenient truth: air travel passengers' willingness to pay to offset their CO2 emissions. *Climatic Change*, 90, pp. 299-313.
Brouwer, R., Martin-Ortega, J. and Berbel, J. (2010). Spatial preference heterogeneity: a choice experiment. *Land Economics*, 86 (3), pp. 552-568.
Brouwer, R., Tesfaye, A. and Pauw, P. (2011). Meta-analysis of institutional-economic factors explaining the environmental performance of payments for watershed services. *Environmental Conservation*, 38 (4), pp. 380-392.
Brown, P., Cabarle, B. and Livernash, R. (1997). *Carbon counts: estimating climate change mitigation in forestry projects*. Washington D.C.: World Resources Institute.
Brown, S. (1996). Tropical forests and the global carbon cycle: estimating state and change in biomass density. In: Apps, M.J. and Price, D.T. (Eds), *Forest Ecosystems. Forest Management and the Global Carbon Cycle*. Berlin: Springer, pp. 13-44.

Brown, S. (1997). *Estimating biomass and biomass change of tropical forests*. A primer. FAO Forestry Paper 134. Rome, Italy: Food and Agriculture Organization of the United Nations.

Brown, S., Gillespie, A.J.R. and Lugo, A.E. (1989). Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest Science*, 35, pp. 881–902.

Burrows, W.H., et al., (2002). Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications. *Global Change Biology*, 8, pp. 769–784.

Burrows, W.H. (1976). *Aspects of nutrient cycling in semi arid mallee and mulga communities*. Ph.D. Thesis, Canberra: Australian National University.

Burrows, W.H., Hoffmann, M.B., Compton, J.F., Back, P.V. and Tait, L.J. (2000). Allometric relationships and community biomass estimates for some dominant eucalypts in Central Queensland woodlands. *Australian Journal of Botany*, 48, pp. 707-714.

Burtraw, D. and Toman, M. (2000). *Ancillary benefits of greenhouse gas mitigation policies*. Climate change issues brief no. 7. Washington, USA.: Resources for the Future

Busch, J., Lubowski, R.N., Godoya, F. et al., (2012). Structuring economic incentives to reduce emissions from deforestation within Indonesia. *PNAS*, 109, pp. 1062–1067.

Cai, B., Cameron, T.A. and Gerdes, G.R. (2011). Distal order effects in stated preference surveys. *Ecological Economics*, 70, pp. 1101-1108.

Cairns, M.A., Olmsted, I., Granados, J., Argaez, J. (2003). Composition and aboveground tree biomass of a dry semi-evergreen forest of México's Yucatan Peninsula. *Forest Ecology and Management*, 186, pp. 125-132.

Cairns, M.A., Brown, S., Helmer, E.H. and Baumgardner, G.A. (1997). Root biomass allocation in the world's upland forests. *Oecologia*, 111, pp. 1–11.

Cameron, T. (2005). Individual option prices for climate change mitigation, *Journal of Public Economics*, 89 pp. 283-301

Cameron, T. and Englin, J. (1997). Respondent experience and contingent valuation of environmental goods. *Journal of Environmental Economics and Management*, 33, pp. 296-313.

Campbell, D., Hutchinson, W.G. and Scarpa, R. (2008). Incorporating discontinuous preferences into the analysis of discrete choice experiments. *Environmental and Resource Economics*, 41, pp. 401-417.

Campbell, D., Hutchinson, W.G. and Scarpa, R. (2009). Using Choice Experiments to Explore the Spatial Distribution of Willingness to Pay for Rural Landscape Improvements. *Environment and Planning A*, 41(1),pp. 97-111.

Canadell, J.G. and Raupach, M.R. (2008). Managing forests for climate change mitigation. *Science*, 320, pp. 1456.

Cannell, M.G.R. (1984). Woody biomass of forest stands. *Forest Ecology and Management*, 8, pp. 299-312

Capoor, K. and Ambrosi, P. (2008). *State and Trends of the Carbon Market 2008*. Washington, D.C.: World Bank Institute.

Carlsson, F., Kataria, M., Krupnick, A., Lampi, E., Lofgren, A., Qin, P., Chung, S. and Sterner, T. (2010). *Paying for mitigation: A multiple country study*. Resources for the Future. Discussion Papers.

Carlsson, F. and Martinsson, P. (2001). Do hypothetical and actual marginal willingness to pay differ in choice experiments? *Journal of Environmental Economics and Management*, 41, pp. 179-192.

Carney, D. (1998). *Approaches to sustainable livelihoods for the rural poor*. ODI Poverty Briefings 2, London.

Carvalho, A. et al., (2011).Forest fires in a changing climate and their impacts on air quality. *Atmospheric Environment*, 45, pp. 5545-5553.

Cattaneo, A. (2008). *How to Distribute REDD Funds Across Countries? A Stock-Flow Mechanism*. United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP), Fourteenth session, Poznan, Poland, 1–12 December, The Woods Hole Research Center, Falmouth, UK.

Cattaneo, A. (2009). Robust design of multiscale programs to reduce deforestation. *Environment and Development Economics*, 16, pp. 455–478.

Cattaneo, A. (2010). Incentives to reduce emissions from deforestation: A stock-flow approach with target reductions. In: Bosetti, V., Lubowski, R. (Eds), *Deforestation and Climate Change: Reducing Carbon Emissions from Deforestation and Forest Degradation*. Cheltenham, UK.: Edward Elgar Publications.

CEC (2003). *2003/0173 Proposal for a Directive establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanism*. Brussels, Belgium: Commission of the European Communities.

Chave, J. et al., (2004.) Error propagation and scaling for tropical forest biomass estimates. *Philosophical Transactions of the Royal Society: Biological Sciences*, 359, pp. 409-420.

Chave, J. et al., (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145, pp. 87-99

Chiba, Y. (1998). Architectural analysis of relationship between biomass and basal area based on pipe model theory. *Ecological Modelling*, 108, pp. 219-225.

Christie, M., Hanley, N. and Hynes, S. (2007). Valuing enhancements to forest recreation using choice experiment and contingent behavior methods. *Journal of Forest Economics*, 13, pp. 75-102.

Church, A. and Ravenscroft, N. (2008). Landowner responses to financial incentive schemes for recreational access to woodlands in South East England. *Land Use Policy*, 25, pp. 1-16.

Clark, D.B. and Clark, D.A. (2000). Landscape-scale variation in forest structure and biomass in a tropical rain forest. *Forest Ecology and Management*, 137, pp. 185–98.

Coase, R.H. (1960). The problem of social cost. *Journal of Law and Economics*, 3, pp. 1-44.

CONAFOR (2008). *Expo Forestal: La importancia del Mercado Voluntario de Carbono*. Comisión Nacional Forestal Unidad de Comunicación Social B29-2008; http://www.conafor.gob.mx/portal/docs/secciones/comunicacion/B29-2008.pdf Accessed 1st January 2012

CONAFOR (2010). Visión de México sobre REDD+. Comisión Nacional Forestal, México.

CONAFOR (2012). *Estadísticas de incendios forestales*. Comisión Nacional Forestal, México.

CONANP (2000). *Natural Protected Area Management Plan for La Primavera*. Comisión Nacional de Áreas Naturales Protegidas, SEMARNAT, México

Corbera, E., Kosoy, N. and Martínez Tuna, M. (2007). Equity implications of marketing ecosystem services in protected areas and rural communities: case studies from Meso-America. *Global Environmental Change*, 17, pp. 365-380.

Corbera, S. and Brown, K. (2008). Building institutions to trade ecosystem services: marketing forest carbon in México. *World Development*, 36, pp. 1956-1979.

Cornelius, W. and Myhre, D. (1998). *The transformation of rural México: reforming the ejido sector*. Center For US-Mexican Studies. San Diego: University Of California.

Cornes, R. and Sandler, T. (1996). *The theory of externalities, public goods and club goods*. Cambridge, UK: Cambridge University Press.

Cortez, R., Saines, R., Griscom, B., Martin, M., De Deo, D., Fishbein, G., Kerkering, J. and Marsh, D. (2010). *A Nested Approach to REDD+; Structuring Effective and Transparent Incentive Mechanisms for REDD+ Implementation at Multiple Scales*. The Nature Conservancy: Arlington, VA, USA and Baker McKenzie: Chicago, IL, USA.

Costanza, R et al., (1997). The value of the world's ecosystems and natural capital. *Nature*, 387, pp. 253–260.

Dagnelie, P., Palm, R., Rondeux, J. and Thill, A. (1985). *Tables de cubage des arbres et des peuplements forestiers*. Gembloux, Presses agronomiques de Gembloux, p. 148.
Dahlman, C.J. (1979). The problem of externality. *Journal of Law and Economics*, 22 (1), pp. 141-162.
Daly, H. (1990). Commentary: Toward some operational principles of sustainable development. *Ecological Economics*, 2, pp. 1-6.
Daw, T. et al., (2011). Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. *Environmental Conservation*, 38 (4), pp. 370-379.
De Groot, R.S. (1992). *Functions of Nature: Evaluation of Nature in Environmental Planning, Management and Decision Making*. Groningen: Wolters-Noordhoff.
De Groot, R.S., Wilson, M.A. and Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41, pp. 393-408.
De Gryzde, S. and Durschinger, L. (2010). *An Integrated REDD Offset Program (IREDD) for Nesting Projects under Jurisdictional Accounting*. San Francisco, CA, USA: Terra Global Capital.
De Jong, B.H.J., Montoya-Gómez, G., Nelson, K., Soto-Pinto, L., Taylor, J. and Tipper, R. (1995). Community forest management and carbon sequestration: a feasibility study from Chiapas, México. *Interciencia*, 20, pp. 409-416.
De Jong, B.H.J., Ochoa Gaona, S., Quechulpa Montalvo, S., Esquivel Bazán, E. and Pérez Hernández, N. (2004). Ch. 7. Economics of Agroforestry Carbon Sequestration. In: Alavalapati, J.R.R. and Mercer, D.E. (Eds), *Valuing Agroforestry Systems*. Kluwer Academic Publishers, The Netherlands, pp. 123-138.
De Jong, B. et al., (2010). Greenhouse gas emissions between 1993 and 2002 from land-use change and forestry in México. *Forest Ecology and Management*, 260, pp. 1689-1701.
De Jong, B.H.J., Tipper, R. and Montoya-Gomez, G. (2000). An economic analysis of the potential for carbon sequestration by forests: evidence from southern México, *Ecological Economics*, 33, pp. 313-327.
DECCW (2010). Private Native Forestry code of Practice Guidelines No. 5. Department of Environment, Climate Change and Water, NSW Australia.
Del Castillo, A. (2011a). *La Primavera, una defensa imposible*. Local Newspaper Milenio. 10 October, 2011. Available online: http://impreso.milenio.com/node/9041077, accessed on 8th April 2012.
Del Castillo, A. (2011b). *La Primavera, inmersa en procesos de extinción*. Milenio Local Newspaper, 6th March 2011, available on line in http://impreso.milenio.com/node/8922367, accessed on 3rd August 2012.
Del Castillo, A. (2011c). *Un Mercado de carbono para salvar la Primavera*. Milenio Local Newspaper, 24th July 2011, available online in http://jalisco.milenio.com/cdb/doc/impreso/8997422, accessed on 3rd August 2012.
Del Castillo, A. (2012a). *La SCT acepta pasos de fauna 'bien hechos'*. Milenio Local Newspaper, 2nd pril 2012, available on line: http://jalisco.milenio.com/cdb/doc/noticias2011/f1fc5af3444d2aacba700a78b82731aa , accessed on 3rd August 2012.
Del Castillo, A. (2012b). *Megaincendio costó más de lo que el estado da al bosque*. Milenio Newspaper. 1st May 2012. Available online: http://jalisco.milenio.com/cdb/doc/noticias2011/1e23963bb6a02e607cb45bf926910f1b, accessed on 12th Aug 12.
Dickinson, B.J., Stevens, T.H., Markowski-Lindsay, M. and Kittredge, D.B. (2012). Estimated participation in US carbon sequestration programs: A study of NIPF landowners in Massachusetts. *Journal of Forest Economics*, 18, pp. 36-46.

Diederich, J. and Goeschl, T. (2011). *Willingness to pay for individual greenhouse gas emissions reductions: evidence from a large field experiment*. Department of Economics, Discussion Paper Series No. 517. University of Heidelberg, Germany.

Dietz, T., Dan, A. and Shwom, R. (2007). Support for climate change policy: social psychological and social structural influences. *Rural Sociology*, 72, pp. 185-214.

Dilworth, J.R. and Bell, J.F. (1971). *Variable probability sampling—variable plot and three P*. Corvallis, Oregon: OSU Book Stores.

Dixon, R.K. et al., (1993). Forest sector carbon offset projects: near-term opportunities to mitigate greenhouse gas emissions. *Water, Air and Soil Pollution*, 70, pp. 561-577.

Drupp, M.A. (2011). Does the Gold Standard label hold its promise in delivering higher Sustainable Development benefits? A multi-criteria comparison of CDM projects. *Energy Policy*, 39 (3), pp. 1213-1227.

EEA (2011). *EU within reach of Kyoto Targets*. European Environment Agency. Available online URL: http://www.eea.europa.eu/pressroom/newsreleases/eu-within-reach-of-kyoto-targets, consulted 30 may 2012.

El Universal (2005). *Consume incendio el bosque La Primavera*. April 30th. Newspaper Article. Available online (19th July 2012): http://www2.eluniversal.com.mx/pls/impreso/noticia.html?id_nota=280968&tabla=notas . México.

El Universal (2012). *Intencional el incendio en La Primavera: funcionario*. Declaration of Alvaro Garcia Chavez Secretary of Rural Development of the State of Jalisco. El Universal, Newspaper 24 April, México.

Elabakidze, L. and McCarl, B.A. (2007). Sequestration offsets versus direct emission reductions: Consideration of environmental co-effects. *Ecological Economics*, 60, pp. 564-571.

Engel. S., Pagiola, S., Wunder, S. (2008). Designing payments for environmental services in theory and practice: an overview of the issues. *Ecological Economics*, 65, pp. 663-674.

Estado de México (2011). Convocatoria para el pago por servicios ambientales hidrologicos 2011. Gaceta del Gobierno. Periodico Oficial del Gobierno del Estado Libre y Soberano de México, No. 27. Toluca de Lerdo, México. 8 de Febrero de 2011.

Ethier, R.G., Poe, G.L., Schulze, W.D. and Clark, J. (2000). A comparison of hypothetical phone and mail contingent valuation responses for green-pricing electricity programs. *Land Economics*, 76, pp. 54-67.

Eyre, N. (2010). Policing carbon: design and enforcement options for personal carbon trading. *Climate Policy*, 10 (4), pp. 432-446.

Farley, J. (2010). Conservation through the economic lens. *Environmental Management*, 45, pp. 26-38.

Fawcett, T. (2010). Personal carbon trading in different national contexts. *Climate Policy*, 10 (4), pp. 339–352.

Fawcett, T. and Parag, Y. (2010). An introduction to personal carbon trading. *Climate Policy*, 10 (4), 329-338.

FEASTA (2008). *Cap and Share: A Fair Way to Cut Greenhouse Gas Emissions, The Foundation for the Economics of Sustainability*. Available Online: www.feasta.org/documents/energy/Cap-and-Share-May08.pdf, accessed 11th August 2012.

Feldpausch, T.R. et al., (2011). Height-diameter allometry for tropical forest trees. *Biogeosciences*, 8, pp. 1-26.

Feng, K., Hubacek, K. and Guan, D. (2009). Lifestyles, technology and CO2 emissions in China: a regional comparative analysis. *Ecological Economics*, 69, pp. 145-154.

Finér, L., Ohashi, M., Noguchi, K. and Hirano, Y. (2011). Factors causing variation in the root biomass in forest ecosystems. *Forest Ecology and Management*, 261, pp. 265-277.

Finus, M. and Rubbelke, T.G. (2008). *Coalition formation and the ancillary benefits of climate policy*. Fondazione Eni Enrico Mattei Nota di Lavoro 62.
Foli, E.G., Alder, D., Miller, H.G. and Swaine, M.D. (2003). Modelling growing space requirements for some tropical forest tree species. *Forest Ecology and Management*, 173, pp. 79-88.
Galindo, L.M. (2009). La economía del cambio climático en México: síntesis. SHCP/SEMARNAT, D.F. México.
Gamez, J.L. (2012). Inicia bosque La Primavera el anio con el 30% del presupuesto que requiere. Notisitema Informa (Radio News) 3rd Jan 2012. Available online: http://www.notisistema.com/noticias/?p=454454, accessed on 12th Aug. 2012.
Garrod, G., Ruto, E., Willis, K., Powe, N. (2012). Heterogeneity of preferences for the benefits of Environmental Stewardship: A latent-class approach. *Ecological Economics*, 76, pp. 104-111.
GEIMÉXICO (2012). *Programa GEI México*. Reportes de Inventario. Available online: http://www.geiMéxico.org/reportes.html, accessed on 12th Aug 2012.
Gill, S.J., Biging, G.S. and Murphy, E.C. (2000). Modeling conifer tree crown radius and estimating canopy cover. *Forest Ecology and Management*, 126, pp. 405-416.
Glenk, K. and Colombo S. (2011). Designing policies to mitigate the agricultural contribution to climate change: an assessment of soil based carbon sequestration and ancillary effects. *Climatic Change*, 105, pp. 43-66.
Gong, Y., Bull, G. and Baylis, K. (2010). Participation in the world's first clean development mechanism forest project: the role of property rights, social capital and contractual rules. *Ecological Economics*, 69, pp. 1292-1302.
Gonzalez, P. et al., (2010). Forest carbon densities and uncertainties from Lidar, Quickbird, and field measurements in California. *Remote Sensing of Environment*, 114, pp. 1561-1575.
Graf-Montero and Bauche-Petersen n.d. El pago de SA como instrumento de conservacion de cuencas. Comision Nacional Forestal. Diponible en: http://www.atl.org.mx/coloquio/images/stories/curricula/sergio_humberto_graf_monteroponesp.pdf, disponible al 20 de Mayo 2012.
Gregory, R., Lichtenstein, S. and Slovic, P. (1993). Valuing environmental resources: a constructive approach. *Journal of Risk and Uncertainty*, 7, pp. 177-197.
Greiner, R., Herr, A. and Stoeckl, N. (2003). *Policies aimed at overcoming impediments to the implementation of on-farm conservation activities*. Paper presented at 4th BioEcon Workshop on the Economics of Biodiversity Conservation, Venice.
Grenier, Y., Blais, L. and Lavoie, E. (1991). Aire minimum d'échantillonnage ou nombre de points de prisme nécessaires pour établir la structure d'un peuplement inéquienne. *Canadian Journal of Forest Research*, 21, pp. 1632-1638.
Grieg-Gran, M., Porras, I. and Wunder, S. (2005). How can market mechanisms for forests environmental services help the poor? Preliminary lessons from Latin America. *World Development*, 33 (9), pp. 1511-1527.
Grosenbaugh, L.R. (1952). Plotless timber estimates—new, fast, easy. *Journal of Forestry*, 50, pp. 32–37.
Grubb, M. and Sato, M. (2009). *Ten (plus one) insights from the EU Emissions Trading Scheme, with reference to emerging systems in Asia*. Climate Strategies, UK.
Haab, T.C. and McConnell, K.E. (2002). *Valuing Environmental and Natural Resources. The Econometrics of Non-Market Valuation*. Cheltenham, UK: Edward Elgar Publishing.
Haase, R. and Haase, P. (1995). Above-ground biomass estimates for invasive trees and shrubs in the Pantanal of Mato Grosso, Brasil. *Forest Ecology and Management*, 73, pp. 29-35.
Hamilton, K., Bayon, R., Turner, G., Higgins, D. (2007). *State of the Voluntary Carbon Markets 2007: Picking Up Steam*. EcoSystem Marketplace and New Carbon Finance. Available at

http://ecosystemmarketplace.com/documents/acrobat/StateoftheVoluntaryCarbonMarket17July.pdf, accessed 1st September 2011.
Hanley, N., Shogren, J.F. and White, B. (1997). *Environmental economics in theory and practice*. MacMillan, England.
Hausman, J.A., McFadden, D. (1984). Specification tests for the multinomial logit model. *Econometrica*, 52, pp. 1219-1240.
Heath, J. and Binswanger, H.P. (1996). Natural resource degradation effects of poverty are largely policy-induced: the case of Colombia. *Environment and Development Economics*, 1, pp. 65–84.
Henders, S. and Ostwald, M. (2012). Forest carbon leakage quantification methods and their suitability for assessing leakage in REDD. *Forests*, 3, pp. 33–58.
Herold, M. et al., (2011). Options for monitoring and estimating historical carbon emissions from forest degradation in the context of REDD+. *Carbon Balance and Management*, 6, p. 13.
Hersch, J. and Viscusi, W.K. (2006). The generational divide in support for environmental policies: European evidence. *Climatic Change*, 77, pp.121-136.
Hines, J.M., Hungerford, H.R. and Tomera, A.N. (1987). Analysis and synthesis of research on responsible environmental behaviour: A metaanalysis. *Journal of Environmental Education*, 18, pp. 1-8.
Horne, P., Boxall, P.C. and Adamowicz, W.L. (2005). Multiple-use management of forest recreation sites: a spatially explicit choice experiment. *Forest Ecology and Management*, 207, pp. 189-199.
Horne, P. (2004). Forest owners' acceptance of incentive-based policy instruments in forest biodiversity conservation: a choice experiment approach. *Silva Fennica*, 40 (1), pp. 169-178.
Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, 69, pp. 1595-1603.
Huxley, J.S. and Tessier, G. (1936). Terminology of relative growth. *Nature*, 137, pp. 780-781.
ICCC (2007). Estrategia Nacional de Cambio Climático México. Comisión Intersecretarial de Cambio Climático. SEMARNAT. México.
INEGI (2001). *Sistema de Cuentas Nacionales de México*. Instituto Nacional de Estadística Geografía e Informática, México
INEGI (2005). *Conjunto nacional de uso de suelo y vegetación a escala 1:250000, Serie III*. DGG-INEGI, México.
INEGI (2007a). *Encuesta Nacional de Ingresos y Gastos de los Hogares 2006*. INEGI. México.
INEGI (2007b). *Censo Agropecuario 2007, IX Censo Ejidal*. Instituto Nacional de Estadistica y Geografia, Aguascalientes, México.
INEGI (2010). *Conjunto nacional de uso de suelo y vegetación a escala 1:250,000 Serie IV*. Instituto Nacional de Estadistica y Geografia. Aguascalientes, México.
INEGI (2011a). *Censos generales de poblacion y vivienda, 1970-2010.* Instituto Nacional de Estadistica y Geografia. Aguascalientes, México. Available online: http://www.inegi.org.mx/default.aspx
INEGI (2011b). *Presentación de resultados encuesta nacional de ingresos y gastos de los hogares ENIGH 2010*. INEGI, México.
Informador (2008). *Continuan congelados nuevos fraccionamientos en Tlajomulco*. 9th September. Available online URL: http://www.informador.com.mx/jalisco/2008/37360/6/continuan-congelados-nuevos-fraccionamientos-en-tlajomulco.htm, accessed on 8th April 2012.
Inforural (2007). *Produce Valle de Tesistan mas maiz en menor superficie*. Available online: http://www.inforural.com.mx/spip.php?article14519, accessed on 8th April 2012.

IPCC (1996). Revised 1996 IPCC Guidelines for national greenhouse gas inventories (3 volumes). Intergovernmental panel on climate change.

IPCC (2000). Good practice guidance and uncertainty management in national greenhouse gas inventories. Intergovernmental panel on climate change.

IPCC (2001). *Climate Change 2001: Mitigation Contribution of Working Group III to the Third Assessment Report of the IPCC*. Cambridge, U.K.: Cambridge University Press.

IPCC (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry, Prepared by the National Greenhouse Gas Inventories Programme. Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. and Wagner, F. (Eds). Published: IGES, Japan.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (Eds). Published: IGES, Japan.

Johnson, E., Nemet, G.F. (2010). *Willingness to pay for climate policy: a review of estimates*. La Follette School Working Paper No. 2010-011. University of Wisconsin, Madison, USA.

Johnston, R.J., Duke J.M. (2009). Willingness to pay for land preservation across states and jurisdictional scale: implications for benefit transfer. *Land Economics*, 85 (2), pp. 217-223.

Kahneman, D. (1986). *Comments. Valuing Environmental Goods: An Assessment of the Contingent Valuation Method*. Totowa: Rowman and Allanheld Publishers, pp. 185-197.

Kilgore, M.A., Snyder, S.A., Schertz, J. and Taff, S.J. (2008). What does it take to get family forest owners to enroll in a forest stewardship-type program? *Forest Policy and Economics*, 10, pp. 507-514.

Kinzig, A.P. et al., (2011). Paying for ecosystem services-Promise and peril. *Science*, 334, pp. 603-604.

Koellner, T., Sell, J. and Navarro, G. (2010). Why and how much are firms willing to invest in ecosystem services from tropical forests? A comparison of international and Costa Rican firms. *Ecological Economics*, 69, pp. 2127-2139.

Kousky, C. and Schneider, S.H. (2003). Global climate policy: will cities lead the way? *Climate Policy*, 3 (4), pp. 359-372.

Krinsky, I. and Robb, A. (1986). Approximating the statistical properties of elasticities. *Review of Economics and Statistics*, 68, pp. 715-19.

Kroeger, T. and Casey, F. (2007). An assessment of market-based approaches to providing ecosystem services on agricultural lands. *Ecological Economics*, 64, pp. 321-332.

Krook Riekkola, A., Ahlgren, E.O. and Soderholm, P. (2011). Ancillary benefits of climate policy in a small open economy: The case of Sweden. *Energy Policy*, 39, pp. 4985-4998.

Krukowska, E. and Carr, M. (2011*). Record surge in CO2 credit volume may hamper 2012 price rebound*. Bloomberg News. Available on-line: http://www.bloomberg.com/news/2011-12-30/record-surge-in-co2-credit-volume-may-hamper-2012-price-rebound.html, consulted on 20th May 2012.

Kuuluvainen, T. (1991). Relationships between crown projected area and components of above-ground biomass in Norway spruce trees in even-aged stands: empirical results and their interpretation. *Forest Ecology and Management*, 40, pp. 243-260.

Lambert, D.M., Sullivan, P., Claassen, R. and Foreman, L. (2007). Profiles of US farm households adopting conservation-compatible practices. *Land Use Policy*, 24, pp. 72-88.

Lancaster, K. (1966). A new approach to consumer theory. *Journal of Political Economy*, 74, pp. 132-157.

Landell-Mills, N. and Porras. I.T. (2002). *Silver bullet or fool's gold: A global review of markets for forest environmental services and their impact in the poor*. London, England: International Institute for Environment and Development.

Layton, D.F. and Brown, G. (2000). Heterogeneous preferences regarding global climate change. *Review of Economics and Statistics*, 82, pp. 616-624.
Lefsky, M.A. et al., (1999). Surface lidar remote sensing of basal area and biomass in deciduous forests of eastern Maryland, USA. *Remote Sensing of Environment*, 67, pp. 83-98.
Lévêque, F. (1999). Externalities, collective goods and the requirement of state's intervention in pollution abatement. In: Carraro, C. and Lévêque, F. (Eds), *Voluntary approaches in environmental policy*. Fondazione Eni Enrico Mattei. Kluwer Academic Publishers, The Netherlands.
Lewis, S.L. et al., (2004). Concerted changes in tropical forest structure and dynamics: evidence from 50 South American long-term plots. *Philosophical Transactions of the Royal Society B: Biological Science*, 359, pp. 421-436.
Li, H., Berrens, R., Bohara, A., Jenkins-Smith, H., Silva, C. and Weimer, D. (2004). Would developing country commitments affect US households' support for a modified Kyoto Protocol? *Ecological Economics*, 48, pp. 329-343.
Li, H., Jenkins-Smith, H.C., Silva, C.L., Berrens, R.P. and Herron, K.G. (2009). Public support for reducing US reliance on fossil fuels: investigating household willingness to pay for energy research and development. Ecological Economics, 68, pp. 731-742.
Linacre, N., Kossoy, A. and Ambrosi, P. (2011). *State and Trends of the Carbon Market 2011*. Washington, DC: The World Bank.
Lindstedt, S. et al., (1986). Home Range, Time, and Body Size in Mammals. *Ecology*, 67 (2), 413-418.
Lockwood, M. (2010). The economics of personal carbon trading. *Climate Policy*, 10 (4), pp. 447-461.
Loera, M.V. (2005). Artesanos en peligro de extincion. *Gaceta Universitaria*, 394, pp. 18-19.
Loftus, T.T. and Kraft, S.E. (2003). Enrolling conservation buffers in the CRP. *Land Use Policy*, 20 (1), pp. 73-84.
Longo, A., Hoyos, D. and Markandya, A. (2012). Willingness to pay for ancillary benefits of climate change mitigation. *Environmental and Resource Economics*, 51, pp. 119-140.
Loomis, J. and Ekstrand, E. (1998). Alternative approaches for incorporating respondent uncertainty when estimating willingness to pay: the case of the Mexican Spotted Owl. *Ecological Economics*, 27, pp. 29-41.
Loomis, J.B. and Rosenberg, R.S. (2006). Reducing barriers in future benefit transfers: Needed improvements in primary study design and reporting. *Ecological Economics*, 60, pp. 343-350.
López-Hoffman, L., Varady, R.G., Flessa, K.W. and Balvanera, P. (2010). Ecosystem services across borders: a framework for transboundary conservation policy. *Frontiers in Ecology and the Environment*, 8, pp. 84–91.
Louviere, J. (2001). Choice experiments: an overview of concepts and issues. In: Bennett, J., Blamey, R. (Eds), *The choice modelling approach to environmental valuation*. Cheltenham, UK: Edward Elgar, pp. 13-36.
Lu, J.L. and Shon, Z.Y. (2012). Exploring airline passengers' willingness to pay for carbon offsets. *Transportation Research Part D.*, 17, pp. 124-128.
Lynch, L., Hardie, I. and Parker, D. (2002). *Analyzing agricultural landowners' willingness to install streamside buffers*. Working Paper 02-01. Department of Agricultural and Resource Economics, The University of Maryland, College Park.
Lynne, G.D. (2002). Agricultural industrialization: a metaeconomics look at the metaphors by which we live. *Review of Agricultural Economics*, 24, pp. 410-427.
Ma, Z., Butler, B.J., Kittredge, D.B. and Catanzaro, P. (2012). Factors associated with landowner involvement in forest conservation programs in the US: Implications for policy design and outreach. *Land Use Policy*, 29, pp. 53-61.

MacFadden, D. (1974). Ch. 4. Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (Ed.), *Frontiers in Econometrics*. New York: Academic Press, pp. 105-142
MacKerron, G.J., Egerton, C., Gaskell, C., Parpia, A. and Mourato, S. (2009). Willingness to pay for carbon offset certification and co-benefits among (high-)flying young adults in the UK. *Energy Policy*, 37, pp. 1372-1381.
MacMillan, D.C., Philip, L., Hanley, N.D. and Alvarez-Farizo, B. (2002). Valuing the non-market benefits of wild goose conservation: a comparison of interview and group based approaches. *Ecological Economics*, 43, pp. 49-59.
MacMillan, D.C., Hanley, N. and Lienhoop, N. (2006). Contingent Valuation: environmental polling or preference engine? *Ecological Economics*, 60, pp. 299-307.
MacMillan, D.C and Phillip, S. (2010). The role of economic incentives in resolving conservation conflicts: the case of wild deer management and habitat conservation. *Human Ecology*, 38 (4), pp. 485-494.
Maddala, G.S. (1983). *Limited-dependent and qualitative variables in econometrics*. Cambridge University Press, USA.
Mani, S. and Parthasarthy, N. (2007). Above-ground biomass estimation in ten tropical dry evergreen forest sites of peninsular India. *Biomass and Bioenergy*, 31, pp. 284-290.
Maniatis, D. and Mollicone, D. (2010). Options for sampling and stratification for national forest inventories to implement REDD+ under the UNFCCC. *Carbon Balance and Management*, 5, p. 9.
Manzano and Balderas Torres (2009). *Diagnostico de emisiones de GEI de una gira internacional de concierto*. Proyecto de Aplicación Profesional. ITESO.
Markham, V. (2009). *US Population, Energy and Climate Change*. New Canaan, Connecticut, US: Center for Environment and Population.
Markowski-Lindsay, M., Stevens, T., Kittredge, D.B., Butler, B.J., Catanzaro, P. and Dickinson, B.J. (2011). Barriers to Massachusetts forest landowner participation in carbon markets. *Ecological Economics*, 71, pp. 180-190.
Martinez, A. (2012). *Revelan satélites daño en bosque. Grafico Animado*. Mural 13 de Mayo. Newspaper Article, Guadalajara, México.
Martínez-Alier, J. (2004). *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*. New Delhi: Oxford University Press.
Martínez-Yrizar, A. et al., (1992). Above-ground phytomass of a tropical deciduous forest on the coast of Jalisco, México. *Journal of Tropical Ecology*, 8, pp. 87-96.
Masera, O.R., Ordóñez, M.J. and Dirzo, R. (1997). Carbon emissions from Mexican forests: current situation and long term scenarios. *Climatic Change*, 35, pp. 265-295.
McCarl, B.A. and Schneider, U.A. (2001). Greenhouse gas mitigation in US Agriculture and forestry. *Science*, 294 (5551), pp. 2481-82.
McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (Ed.), *Frontiers in Econometrics*. New York, USA: Academic Press, pp. 105-142.
McPherson, E.G. et al., (2006). *Midwest community tree guide: benefits, costs, and strategic planting*. Gen. Tech. Rep. PSW-GTR-199. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Davis, CA: Albany, CA: US
Merlín-Bermudes, E. (2005). *Estudios sobre el conocimiento de algunas especies de encino en Durango, México*. Doctoral Thesis. Universidad Autónoma de Nuevo León, México.
Meyerhoff, J., Liebe, U. and Hartje, V. (2009). Benefits of biodiversity enhancement of nature-oriented silviculture: Evidence from two choice experiments in Germany. *Journal of Forest Economics*, 15, pp. 37-58.
Moran, D. et al., (2008). *UK marginal abatement cost curves for the agriculture and land use, land use change and forestry sectors out to 2022, with qualitative analysis of options to 2050*. Final report to the Committee on Climate Change.

www.knowledgescotland.org/images_db/ukmarginalabatementcostcurves.pdf. Accessed 29 May 2012.
Morrison, M. and Bennett, J. (2004). Valuing New South Wales rivers for use in benefit transfer. *The Australian Journal of Agricultural and Resource Economics*, 48 (1), pp. 591-612.
Morrison, M. and Bergland, O. (2006). Prospects for the use of choice modelling for benefit transfer. *Ecological Economics*, 60, pp. 420-428.
Muñoz Piña, C., Guevara, A., Torres, J.M. and Braña, J. (2008). Paying for the hydrological services of México's forests: Analysis, negotiations and results. *Ecological Economics*, 65, pp. 725–736.
Muradian, R., Corbera, E., Pascual, U., Kosoy, N. and May, P.H. (2010). Reconciling theory and practice: an alternative conceptual framework for understanding payments for environmental services. *Ecological Economics*, 69, pp. 1202-1208.
Murali, K.S., Bhat, D.M. and Ravindranath, N.H. (2005). Biomass estimation equation for tropical deciduous and evergreen forests. *International Journal of Agricultural Resources, Governance and Ecology*, 4, pp. 81–92.
Murray, J. and Dey, C. (2009). The carbon neutral free for all. *International Journal of Greenhouse Gas Control*, 3 (2), pp. 237–48.
Naesset, E. et al., (2011). Model-assisted regional forest biomass estimation using LiDar and InSAR as auxiliary data: a case study from a boreal forest area. *Remote Sensing of Environment*, 115, pp. 3599-3614.
NASA (2012). *Fire chars a forest near Guadalajara*. News. Available online URL: http://earthobservatory.nasa.gov/IOTD/view.php?id=78058&src=eoa-iotd accessed 28th May 2012.
Návar, J. (2009). Allometric equations for tree species and carbon stocks for forests of northwestern México. *Forest Ecology and Management*, 257, pp. 427-434.
Návar, J. (2010). Measurement and assessment methods of forest aboveground biomass: a literature review and the challenges ahead. In: Momba, M. and Bux, F. (Eds), *Biomass*. Sciyo, Croatia.
Návar-Cháidez, J.J. (2010). The temperate forests of the state of Nuevo León: sustainable management for goods and environmental services. *Madera y Bosques*, 16 (1), pp. 51-69.
Nemet, G.F., Holloway, T. and Meier, P. (2010). Implication of incorporating air-quality co-benefits into climate change policymaking. *Environmental Research Letters*, 5, 014007. DOI:10.1088/1748-9326/5/1/014007.
Newton, P., Nichols, E.S., Endo, W. and Peres, C.A. (2012). Consequences of actor level livelihood heterogeneity for additionality in a tropical forest payment for environmental services programme with an undifferentiated reward structure. *Global Environmental Change*, 22, pp. 127-136.
Niemeier, D., Gould, G., Karner, A., Hixson, M., Bachmann, B., Okma, C., Lang, Z. and Heres del Valle, D. (2008). Rethinking downstream regulation: California's opportunity to engage households in reducing greenhouse gases. *Energy Policy*, 36, pp. 3436–3447.
Nomura, N. and Akai, M. (2004). Willingness to pay for green electricity in Japan as estimated through contingent valuation method. *Applied Energy*, 78, pp. 453-463.
NORAD (1993). *El enfoque de marco lógico*. Manual para la planificación de proyectos orientados mediante objetivos. NORAD Agencia Noruega para la Cooperación y Desarrollo. IUDC-CEDEAL Madrid, España.
North (1990). *Institutions, institutional change and economic performance*. Cambridge University Press, UK.

O'Grady, A.P., Chen, X., Eamus, D. and Hutley, L.B. (2000). Composition, leaf area index and standing biomass of eucalypt open forests near Darwin in the Northern Territory, Australia. *Australian Journal of Botany*, 48, pp. 629-638.

OECD (2002). *Ancillary benefits and costs of GHG mitigation: policy conclusions. Working Party on Global and Structural Policies*. ENV/EPOC/GSP(2001)13/FINAL. Paris, France: Organisation for Economic Co-operation and Development.

Ohdoko, T. (2008). *Comparison of complete combinatorial and likelihood ratio tests: Empirical findings from residential choice experiments*. Kobe University, Japan. Selected paper prepared for presentation at the American Agricultural Economics Association, Annual Meeting, Orlando FL, July 2008

Ostrom, E. (2000). Collective action and the evolution of social norms. *Journal of Economic Perspectives*, 14, pp. 137-158.

Ovchinnikova, N.V., Czap, H.J., Lynne, G.D. and Larmier, C.W. (2009). I don't want to be selling my soul: Two experiments in environmental economics. *Journal of Socio-Economics*, 39, pp. 221-229.

Pagiola, S., Bishop, J. and Landell-Mills, N. (2002). Making market-base mechanisms work for forest and people. In: S. Pagiola, J. Bishop and N. Landell-Mills (Eds), *Selling forest environmental services: market-based mechanisms for conservation and development*. London: Earthscan, chap.15.

Pagiola, S. and Platais, G. (2007). *Payments for environmental services: from theory to practice*. Washington, USA: World Bank.

Pagiola, S. 2008. Payments for environmental services in Costa Rica. *Ecological Economics*, 65: 712-724

Palacios-Sanchez, L.A. et al., (2006). Clasificador genérico de objetos en imágenes ETM+. *Agrociencia*, 40, pp. 613-626.

Palley, M.N. and Horwitz, L.G. (1961). Properties of some random and systematic point sampling estimators. *Forest Science*, 7, pp. 52-65.

Parag, Y. and Eyre, N. (2010). Barriers to personal carbon trading in the policy arena, *Climate Policy*, 10 (4), pp. 353-368.

Patterson, M. (2012). Who and what are carbon markets for? Politics and the development of climate policy. *Climate Policy*, 12 (1), pp. 82-97.

Paz-Pellat, F. et al., (2010). *Documento de referencia para la estimacion de la cobertura aerea anual de la vegetacion y su tendencia de cambio en el estado de Chiapas*. Colegio de Postgraduados, México.

Pearce, D.W. (1992). *The secondary benefits of greenhouse gas control*. CSERGE Working Paper 92-12. London, England: CSERGE University College.

Pearce, D.W. (2000). Policy Frameworks for the Side Effects of Climate Change Policies in OECD. Ancillary Benefits and Costs of Greenhouse Gas Mitigation. Proceedings of an Expert Workshop. Organisation for Economic Co-operation and Development, Paris, France.

PECC (2008). Programa Especial de Cambio Climático 2009-2012, Secretaría del Medio Ambiente y Recursos Naturales, México.

Pedroni, L., Dutschke, M., Streck, C. and Porrua, M.E. (2009). Creating incentives for avoiding further deforestation: The nested approach. *Climate Policy*, 2, 267–276.

Perdan, S. and Azapagic, A. (2011). Carbon trading: Current schemes and future for developments. *Energy Policy*, 39, pp. 6040-6054.

Perez Vega, I. (2012). *Tlajomulco, una bomba de tiempo 'contenida'*. Local Newspaper Milenio, 13th February 2012, available online: http://impreso.milenio.com/node/9111967, accessed on 8th April 2012.

Perman, R. et al., (2003). *Natural Resources and Environmental Economics*. Pearson Addison Wesley. Third Edition. England.

Peskett, L. (2011*). Benefit Sharing in REDD+: Exploring the Implications for Poor and Vulnerable People*. London, UK: World Bank/REDD-Net.
Peters-Stanley, M. and Hamilton, K. (2012). *Developing dimension: state of the voluntary carbon markets*. Ecosystem Marketplace/Forest Trends, Bloomberg New Energy Finance, US
Peters-Stanley, M., Hamilton, K., Marcello, T. and Sjardin, M. (2011). *Back to the Future: State of the Voluntary Carbon Markets 2011*. Ecosystem Marketplace: Washington, DC, USA and Bloomberg New Energy Finance: New York, NY, USA.
Petrolia, D.R., Bhattacharjee, S., Hudson, D. and Herndon, C.W. (2010). Do Americans Want Ethanol? A Comparative Contingent-Valuation Study of Willingness to Pay for E-10 and E-85. *Energy Economics*, 32, pp. 121-128.
Petrzelka, P., Malin, S. and Gentry, B. (2012). Absentee landowners and conservation programs: Mind the gap. *Land Use Policy*, 29, pp. 220-223.
Phelps, J., Webb, E. and Agrawal, A. (2010). Does REDD+ threaten to recentralize forest governance? *Science*, 328, pp. 312–313.
Phillips, O.L., Malhi, Y., Higuchi, N., Laurance, W.F., Nunez, P.V., Vasquez, R.M. et al., (1998). Changes in the carbon balance of tropical forests: evidence from long-term plots. *Science*, 282, pp. 439–42.
Pigou, C. (1932). *The Economics of Welfare*. London: MacMillan.
Pinard, M.A. (1995). *Carbon retention by reduced-impact logging*. Ph.D. Dissertation. Department of Botany, University of Florida, Gainesville, Florida, USA.
Piqué, M., Obon, B., Condés, S. and Saura, S. (2011). Comparison of relascope and fixed-radius plots for the estimation of forest stand variables in northeast Spain: an inventory simulation approach. *European Journal of Forest Research*, 130, pp. 851-859.
Plan Vivo (2012). Website www.planvivo.org accessed on the 10th of February 2012.
Plantinga, A.J. andWu, J. (2003). Co-benefits from carbon sequestration in forests: evaluating reductions in agricultural externalities from an afforestation policy in Wisconsin. *Land Economics*, 79 (1), pp. 74-85.
Poe, G., Giraud, K. and Loomis, J. (2005). Computational methods for measuring the difference of empirical distributions. *American Journal of Agricultural Economics*, 87, pp. 353-365.
Presidencia (2007). Plan Nacional de Desarrollo 2007-2012. Presidencia de la República de los Estados Unidos Mexicanos. http://pnd.calderon.presidencia.gob.mx/index.php?page=bosques-y-selvas. México
Putten, I.E., Jennings, S.M., Louviere, J.J. and Burgess, L.B. (2011). Tasmanian landowner preference for conservation incentive programs: A latent class approach. *Journal of Environmental Management*, 92, pp. 2647-2656.
RAN (2011). *Poligonos de Areas Ejidales*. Registro Agrario Nacional, México.
Raux, C. and Marlot, G. (2005). A system of tradable CO2 permits applied to fuel consumption by motorists. *Transport Policy*, 12, pp. 255–265.
Rawls, J. (1971). *A theory of justice*. Harvard University Press, EUA.
Reineke, L.H. (1933). Perfecting a stand-density index for even-aged forests. *Journal of Agricultural Research*, 46, pp. 627-638.
Richards, K. and Stokes, C. (2004). A review of forest carbon sequestration cost studies: A dozen years of research. *Climatic Change*, 63, pp. 1-48.
Rico Garcia-Amado, L., Ruiz Perez, M., Reyes Escutia, F., Barrasa Garcia, S. and Contreras Mejia, E. (2011). Efficiency of payments for environmental services: equity and additionality in a case study from a Biosphere Reserve in Chiapas, México. *Ecological Economics*, 70, pp. 2361-2368.
Rolfe, J., Bennett, J. and Louviere, J. (2000). Choice modelling and its potential application to tropical rainforest preservation. *Ecological Economics*, 35 (2), 289-302.

Rolfe, J. and Bennett, J. (2001). Framing Effects. In: Bennett, J., Blamey, R. (Eds), *The choice modelling approach to environmental valuation*. Cheltenham, UK, Edward Elgar, pp. 202-224
Rolfe, J. and Bennett, J. (2006). *Choice modelling and the transfer of environmental values*. Cheltenham, UK: Edward Elgar.
Romijn, E. et al., (2012). Assessing capacities of non-Annex I countries for national forest monitoring in the context of REDD+. *Environmental Science and Policy*, 19-20, pp. 33-48.
Rondeux, J. (2010). La mesure des arbres et des peuplements forestiers. Les Presses agronomiques de Gembloux a.s.b.l., Gembloux Bélgica. Translated to Spanish by de Barrionuevo-Días, A., García-Moreno, R., Díaz de Almansa, A. Medición de Árboles y Masas Forestales. Ediciones Mundi-Prensa. España.
Rosenberger, R.S. and Phipps, T.T. (2007). Correspondence and Convergence in Benefit Transfer Accuracy: A Meta-Analytic Review of the Literature. In: Navrud S., Ready, R. (Eds), *Environmental Values Transfer: Issues and Methods*. Dordrecht, The Netherlands: Kluwer Academic Publishers.
Sagar, R. and Singh, J.S. (2006). Tree density, basal area and species diversity in a disturbed dry tropical forest of northern India: implications for conservation. *Environmental Conservation*, 33, pp. 256-262.
Samuelson, P.A. (1954). The pure theory of public expenditure. *The Review of Economics and Statistics*, 36 (4), pp. 387-389.
Sandbrook, C., Nelson, F., Adams, W.M. and Agrawal, A. (2010). Carbon, forests and the REDD paradox. *Oryx*, 44 (3), pp. 330–334.
Santiago-Pérez, A.L. and Villavicencio-García, R. (2007). *Multiple analyses of environmental and structural variables to characterization of Quercus and Pinus in the La Primavera, Jalisco, México*. Poster presented at The Annual Meeting of the Association for Tropical Biology and Conservation, Morelia, México.
Sarmiento, G., Pinillos, M. and Garay, I. (2005). Biomass variability in tropical American lowland rainforests. *Ecotropicos*, 18, pp. 1-20.
Sautter, J., Ovchinnikova, N.V., Kruse, C. and Lynne, G.D. (2011). Farmers' decisions regarding carbon sequestration: a metaeconomic view. *Society & Natural Resources*, 24, pp.133-147.
SBSTA (2011a). Views on methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. Submissions from countries. Subsidiary Body for Scientific and Technological Advice Thirty-fifth session Durban, 28 November to 3 December 2011 FCCC/SBSTA/2011/MISC.7
SBSTA (2011b). Report on the expert meeting on forest reference emission levels and forest reference levels for implementation of REDD-plus activities. Note by the secretariat. Subsidiary Body for Scientific and Technological Advice Thrity-fifth session. Durban 28 November to 3 December. FCCC/SBSTA/2011/INF.18
SBSTA (2012). Subsidiary Body for Scientific and Technological Advice. Thirty-sixth Session. Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. Views on issues identified in decision 1/CP.16, paragraph 72 and appendix II. United Nations Framework Convention on Climate Change. FCCC/SBSTA/2010/MISC.1
Scanlan, J.C. (1991). Woody overstorey and herbaceous understorey biomass in Acacia harpophylla (brigalow) woodlands. *Australian Journal of Botany*, 16, pp. 521–529.

Scarpa, R., Gilbride, T.J., Campbell, T. and Hensher, D.A. (2009). Modelling attribute non-attendance in choice experiments for rural landscape valuation. *European Review of Agricultural Economics*, 36 (2), pp. 151-174.
Schelling, T.C. (1997). The cost of combating global warming: facing the tradeoffs. *Foreign Affairs*, 76 (6), pp. 8–14.
Schelling, T.C. (1998). *Costs and Benefits of Greenhouse-Gas Reduction*. Washington, DC: American Enterprise Institute Press.
Schelling, T.C. (2002). What makes greenhouse sense? Time to rethink the Kyoto Protocol. *Foreign Affairs*, 81 (3), pp. 2–9.
Schreuder, H.T., Ernst, R. and Ramirez-Maldonado, H. (2004). *Statistical techniques for sampling and monitoring natural resources*. Gen. Tech. Rep. RMRS-GTR-126. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station.
Scullion J. et al., (2011). Evaluating the environmental impact of payments for environmental services in Coatepec (México) using remote sensing and on-site interviews. *Environmental Conservation*, 38 (4), pp. 426-434.
SEMARNAT (1988). *Ley General del Equilibrio Ecológico y Protección al Ambiente*. SEMARNAT. Diario Oficial de la Federación, publicada inicialmente el 28 de Enero de 1988.
SEMARNAT (2009). *México. Cuarta comunicación nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático*. SEMARNAT, México.
SEMARNAT (2010). *Volumen de la produccion forestal maderable por region y municipio segun grupo de especies 2008-2009*. Secretaría de Medio Ambiente y Recursos Naturales, Delegación en el Estado. Subdelegación de Gestión para la Protección Ambiental y Recursos Naturales.
SEMARNAT (2012a). *Ley General de Cambio Climático*. SEMARNAT 6 de Junio de 2012, Diario Oficial de la Federación, México.
SEMARNAT (2012b). *Ley General de Desarrollo Forestal Sustentable*. SEMARNAT, Diario Oficial de la Federación, adiciones publicadas el 4 de Junio de 2012.
SEMARNAT/SAGARPA (2009). NORMA Oficial Mexicana NOM-015-SEMARNAT/SAGARPA-2007, Que establece las especificaciones técnicas de métodos de uso del fuego en los terrenos forestales y en los terrenos de uso agropecuario. Diario Oficial de la Federacion 16 Enero 2009. México.
SENER (2010). Sistema de Información Energética. Secretaría de Energía. sie.energia.gob.mx
Shaw, J.D. (2006). Reineke's Stand Density Index: Where are we and where do we go from here? Proceedings: Society of American Foresters 2005 National Convention. October 19-23, 2005, Ft. Worth, TX.
Shingleton, A. (2010). Allometry: the study of biological scaling. *Nature Education Knowledge*, 1, p. 2.
SIEM (2012). Estadísticas por municipio, tipo y rango de empleados. Sistema de Información Empresarial Mexicano. Available online: http://www.siem.gob.mx/siem/estadisticas/muntamanoPublico.asp?qedo=14&tam=4&p=1, accessed on 12th Aug 2012.
Singh, L. and Singh, J.S. (1991). Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. *Annals of Botany*, 68, pp. 263–273.
Skutsch, M. et al., (2011). Dealing with locally-driven degradation: A quick start option under REDD+. *Carbon Balance and Management*, 6, p. 16.
Skutsch, M. (Ed.) (2011) *Community forest monitoring for the carbon market. Opportunities under REDD*. United Kingdom: Earthscan
Skutsch, M. and Jong B. de (2010). The permanence debate. *Science*, 327, p. 107.

Skutsch, M. and Trines E. (2010). *Understanding Permanence in REDD+*, K:TGAL Policy Note 6. Available at www.communitycarbonforestry.org, consulted online 20th March 2012.
Solomon, B.D. and Johnson, N.H. (2009). Valuing climate protection through willingness to pay for biomass ethanol. *Ecological Economics*, 68, pp. 2137-2144.
Spash, L. (2010). The brave new world of carbon trading. *New Political Economy*, 15 (2), pp. 169-195.
State of Mexico (2011). Convocatoria para el pago por SA hidrologicos 2011. Gaceta del Gobierno. Periodico Oficial del Gobierno del Estado Libre y Soberano de Mexico, No. 27. Toluca de Lerdo, Mexico. 8 de Febrero de 2011.
Sterk, W., Mersmann, F. (2011). *Domestic Emission Trading Systems in Developing Countries - State of Play and Future Prospects*. JIKO Policy Paper 2/2011. Wuppertal, Germany: Institute for Climate, Environment and Energy.
Stern, N. (2006). *Stern review on the economics of climate change*. UK: Cambridge University Press.
Stevens, T.H., White, S., Kittredge, D.B., Dennis, D. (2002). Factors affecting NIPF landowner participation in management programs: a Massachusetts case study. *Journal of Forest Economics*, 8 (3), pp. 169-184.
Strassburg, B. et al., (2009). Reducing emissions from deforestation-The "combined incentives" mechanism and empirical simulations. *Global Environmental Change*, 19 (2), pp. 265-278.
Suganuma, H. et al., (2006). Stand biomass estimation method by canopy coverage for application to remote sensing in an arid area of Western Australia. *Forest Ecology and Management*, 222, pp. 75-87.
Sullivan, J., Amacher, G.S. and Chapman, S. (2005). Forest banking and forest landowners forgoing management rights for guaranteed financial returns. *Forest Policy and Economics*, 7, pp. 381-392.
Swickard, N. and Carnahan, K. (2010). Integrating project and national REDD+; the importance of the private sector. In: Zhu, X., Ravnkilde Møller, L., De Lopez, T., Romero, M.Z., (Eds), *Pathways for Implementing REDD+*. Roskilde, Denmark: UNEP Risø Centre.
Tadaki, Y., Shidei, T., Sakasegawa, T. and Ogino, K. (1961). Studies on productive structure of forest. II. Estimation of standing crop and some analyses on productivity of young birch stand (Betulaplatyphylla). *Journal of the Japanese Forestry Society*, 43, pp. 19–26.
Thoumi, G. (2011). Community Forest Monitoring for the Carbon Market: Opportunities under REDD. In: Skutsch, M. (Ed.). London, UK,: Earthscan.
Thurston, W. (2006). Non-market valuation on the internet. In: Alberini, A., Kahn, J.R. (Eds) *Handbook of Contingent Valuation*. Cheltenham, UK: Edward Elgar.
Tietenberg, T. (2003). The tradable-permits approach to protecting the commons: lessons for climate change. *Oxford Review of Economic Policy*, 19 (3), pp. 400-419.
Toledo, A. (2012). *Provoca sequia ventas de pánico ganadero*. Local Newspaper Milenio. 9 January. Available online: http://jalisco.milenio.com/cdb/doc/impreso/9091958, accessed on 8th April 2012.
Tseng, W.C. and Chen, C.C. (2008). Valuing the Potential Economic Impact of Climate Change on the Taiwan Trout. *Ecological Economics*, 65 (2), pp. 282-291.
UN (2010). Report of the Secretary-General's high-level advisory group on climate change financing. United Nations, New York.
UN (2003). Integrated Environmental and Economic Accounting 2003, Studies in Methods. Handbook on National Accounting, Series F, No. 61, Rev. 1. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and development, World Bank (ST/ESA/STAT/SER.F/61/Rev.1) SEEA 2003

UN (2010). Report of the Secretary-General's high-level advisory group on climate change financing. United Nations, New York.
UNECE (2008). Measuring sustainable development; UNECE, OECD and Eurostat Working Group on Statistics for Sustainable Development. United Nations, New York and Geneva.
UNESCO (2011). Man and the Biosphere Programme. United Nations Educational, Scientific and Cultural Organization. http://www.unesco.org/mabdb/br/brdir/directory/contact.asp?code=MEX, accessed September 29th 2011.
UNFCCC (1992). United Nations Framework Convention on Climate Change: Text (UNEP/WMO, Geneva).
UNFCCC (1997). Kyoto protocol to the UNFCCC. FCCC/CP/1997/7/Add.1, Decision 1/CP.3, Annex 7.
UNFCCC (1998). Report of the conference of the parties on its third session, held at Kyoto from 1 to 11 December, 1997. Addendum. FCCC/CP/1997/7/Add.1. 25 March 1998
UNFCCC (2002). Report of the conference of the parties on its seventh session, held at Marrakesh from 29 October to 10 November 2001. Addendum. FCCC/CP/2001/13/Add.1.
UNFCCC (2004). Report of the conference of the parties on its ninth session, held at Milan from 1 to 12 December 2003. Addendum. FCCC/CP/2003/6/Add.2., 30 March 2004.
UNFCCC (2010a). Report of the conference of the parties on its fifteenth session, held in Copenhagen held from 7 to 19 December 2009. Addendum. FCCC/CP/2009/11/Add.1. 30 March 2010.
UNFCCC (2010b). Annex 5: Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forest and enhancement of forest carbon stocks in developing countries. FCCC/CP/2010/2
UNFCCC (2011a). Compilation of information on nationally appropriate mitigation actions to be implemented by Parties not included in Annex I to the Convention. FCCC/AWGLCA/2011/INF.1
UNFCCC (2011b). Report of the conference of the parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum. FCCC/CP/2010/7/Add.1. 15 March 2011.
UNFCCC (2011c). Consideration of further commitments for Annex I parties under the Kyoto Protocol. United Nations Framework Convention on Climate Change. FCCC/KP/AWG/2011/L.3/Add.6 10 December 2011. Canada, Russia Japan, expressed.
UNFCCC (2012a). Report of the conference of the parties on its seventeenth session, held in Durban from 28 November to 11 December 2011. Addendum. FCCC/COP/2011/9/Add.1.
UNFCCC (2012b). Non-Annex I national communications. United Nations Framework Convention on Climate Change. Available online: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php, by 26th April 2012.
UNFCCC (2012c). Report of the conference of the parties on its seventeenth session, held in Durban from 28 November to 11 December 2011. Addendum. FCCC/CP/2011/9/Add.2 Decision 12/CP.17: Guidance on systems for providing information on how safeguards are addressed and respected and modalities relating to forest reference emission levels and forest reference levels as referred to in decision 1/CP.16.
UNFCCC (2012d). Minimum Values for Forests (A/R Projects). Designated National Authorities, México. Available online, accessed 20 May 2012.

Van Breugel, M. et al., (2011). Estimating carbon stock in secondary forests: Decisions and uncertainties associated with allometric biomass models. *Forest Ecology and Management*, 262, pp. 1648-1657.
Van Bueren, M. and Bennett, J. (2004). Towards the Development of a Transferable Set of Value 30 Estimates for Environmental Attributes. *Australian Journal of Agricultural and Resource Economics*, 48, pp. 1-32.
Van der Werf, G.R. et al., (2009). CO2 emissions from forest loss. *Nature Geoscience,* 2, pp. 737-738.
Van Noordwijk, M., Suyanto Velarde, S., Purnomo, H., Hoan, D.T. and Hoang, M.H. (2011). *Stakeholder Perspectives on "Fair and Efficient" Benefit Distribution Along the C-REDD Distribution Chain*. Bogor, Indonesia: World Agroforestry Centre.
Vance, E. (2012). México passes climate-change law. *Nature*. DOI:10.1038/nature.2012.10496
VCS (2012). Jurisdictional and Nested REDD Initiative: Summary of Technical Recommendations; Verified Carbon Standard Technical Recommendations; Verified Carbon Standard (VCS) Association: Washington, DC, USA, 23 February 2012; p. 9. Available online: http://www.v-c-s.org/sites/v-c-s.org/files/Summary%20of%20Technical%20Recommendations%20V2%200.pdf (accessed on 27th February 2012).
Viana, V.M. (2008). Bolsa Floresta: um instrumento innovador para a promoção da saúde em comunidades tradicionais na Amazônia. *Estudos Avançados,* 22 (64), pp. 143-153.
Victoria-Hernandez, A. et al., (2011).Generacion de información de uso de suelo y vegetación proyectos y convenios escala 1:50000. Instituto Nacional de Estadistica y Geografia, México. Available online: http://www.inegi.org.mx/eventos/2011/conf_ibero/doc/ET6_46_HERN%C3%81NDEZ.pdf Accessedon 20 May 2012.
Viscusi, W.K. and Zeckhauser, R.J. (2006). The perception and valuation of the risks of climate change: a rational and behavioral blend. *Climatic Change*, 77, pp. 151-177.
Voss, J.P. (2007). Innovation processes in governance: the development of 'emissions trading' as a new policy instrument. *Science and Public Policy*, 34, pp. 329-343.
WCED (1987). *Our Common Future: World Commission of Environment and Development*. World Commission on Environment and Development. Oxford and New York: Oxford University Press.
Welsch, H. and Kuhling, J. (2009). Determinants of pro-environmental consumption: the role of reference groups and routine behavior. *Ecological Economics*, 69, pp. 166-176.
West, G.B., Brown, J.H. and Enquist, B.J.(1999). A general model for the structure and allometry of plant vascular system. *Nature*, 400, pp. 664–667.
Whittaker, R.H. (1966). Forest dimensions and production in the Great Smoky Mountains. *Ecology*, 47, pp. 103–121.
Wiersum, F. and Arts, B. (2009). FLEGT: a government initiative to stimulate forest governance. Forest and Nature Conservation Policy Group. Wageningen UR. Presentation made at the seminar 'FLEGT beyond the "T": Governance visions in the timber chain.' Wageningen University, the Society of Tropical Forests (VTB), the Royal Tropical Institute (KIT) and the Ministry of Agriculture, Nature and Food Quality of The Netherlands.
Willis, K.G. and Garrod, G.D. (1999). Angling and recreation values of low-flow alleviation in rivers. *Journal of Environmental Management*, 57, pp. 71–83.
Wilson, M.A. and Hoehn, J.P. (2006). Valuing environmental goods and services using benefit transfer: The state-of-the art and science. *Ecological Economics*, 60, pp. 335-342.
Wiser, R.H. (2007). Using contingent valuation to explore willingness to pay for renewable energy: a comparison of collective and voluntary payment vehicles. *Ecological Economics*, 62, pp. 19-32.

Wohar, M. (1988). Alternative versions of the Coase theorem and the definition of transaction costs. *Quarterly Journal of Business and Economics*, 27 (1), pp. 3-19.
Woodward, R.T. and Wui, Y.S. (2001). The economic value of wetland services: a meta-analysis. *Ecological Economics*, 37 (2), pp. 257-270.
Wunder, S. (2005). *Payments for environmental services: some nuts and bolts*. Occasional Paper No. 42, CIFOR, Bogor.
Wunder, S. (2009). Can payments for environmental services reduce deforestation and forest degradation? In: Angelsen, A. (Ed.), *Realising REDD+; National Strategy and Policy Options*. Bogor Barat, Indonesia: Center for International Forestry Research
Yao, T. et al., (2011). Measuring forest structure and biomass in New England forest stands using Echidna ground-based lidar. *Remote Sensing of Environment*, 115, pp. 2965-2974.
Zavala-Chávez, F. (2001). Introducción a la ecología de la regeneración natural de encinos. Universidad Autónoma Chapingo, México.
Zerbe, R.O. (1980). The problem of social cost in retrospect. *Research in Law and Economics*, 2, pp. 83-102.
Zerbe, R.O. and McCurdy, H.E. (1999). The failure of market failure. *Journal of Policy Analysis and Management*, 18 (4), pp. 558-578.
Zianis, D. (2008) Predicting mean aboveground forest biomass and its associated variance. *Forest Ecology and Management*, 256, pp. 1400-1407.
Zianis, D. and Mencuccini, M. (2004). On simplifying allometric analyses of forest biomass. *Forest Ecology and Management*, 187, pp. 311–332.
Ziegler, A., Schwarzkopf, J. and Hoffmann, V.H. (2012). Stated versus revealed knowledge: determinants of offsetting CO2 emissions from fuel consumption in vehicle use. *Energy Policy*, 40, pp. 422-431.

Annexes

Annex I: Form used in the Forest inventory

The formats used to register the information of the forest inventory as described in Chapters 4 and 5 is presented below. The formats have been modified to enhance readability.

Proyecto: Diseño de un Mercado de Servicios Ambientales Bosque La Primavera

DARWIN INITIATIVE

1. Información General del Sitio de Muestreo

ID sitio ________ Llenó ________ Altitud ________ [msnm]

Fecha ________ | Hora Inicio ________ | Hora Final ________

Pendiente ☐ [%]

Exposición | N | S | E | O | NO | NE | SE | SO |

Responsable ____________________
Brigadistas ____________________
Nombre predio ____________________
Tenencia ____________________

Vegetación	Cobertura esperada
□ Pino	□ <30% □ 30-60% □ >60%
□ Encino	Cobertura encontrada
□ Encino-Pino	□ <30% □ 30-60% □ >60%

2. Ruta y observaciones de condición de camino

Tipo suelo | □ Regosol □ Litosol

Fisiografía | □ Valle □ Ladera □ Meseta □ Lomerío

Sitio anterior ____________________
Tiempo transcurrido de traslado ☐

Descripción

Condiciones climáticas

Descripción

3. Estrato

	Descripción General Vegetación (Condición, Especies, Cobertura, Impactos, Renuevos)
Arbóreo	
Arbustivo	
Herbáceo	
Suelo	

Impactos: incendios (subterráneo, copa, superficial, hay regeneración?), pastoreo, erosión, tala, cambio uso de suelo, minería, plagas, enfermedades, presencia humana.

4. Croquis

Observaciones

Error GPS +/- [m]

% cubierto hierbas

% cubierto suelo desnudo

X
Y

X
Y

X
Y

X
Y

5. Datos de arbustos

No.	Nombre	Altura [cm]	Diámetro copa [cm]	Diámetros basales [cm]	ID Foto

6. Datos Arbolado Fecha ____________

Llenó

ID Sitio.	No. Arb.	Genero y Especie	Cond	DAP [cm]	Comentario	Foto

ID Sitio.	No. Arb.	Genero y Especie	Cond	DAP [cm]	Comentario	Foto

6. Datos Arbolado

Llenó Fecha

ID Sitio.	No. Arb.	Diámetro copa [m]		Comentario
		a	b	

ID Sitio.	No. Arb.	Diámetro copa [m]		Comentario
		a	b	

6. Datos Arbolado

Llenó Fecha

ID Sitio.	No. Arb.	Altura [m, %, %, %]				ID Foto(s)
		Distancia	a.Copa	b.1aRama	c.Base	

ID Sitio.	No. Arb.	Altura [m, %, %, %]				ID Foto(s)
		Distancia	a.Copa	b.1aRama	c.Base	

Annex II: Questionnaire applied to citizens.

The questionnaire used to evaluate the potential valuation and potential demand for forest carbon services as described in Chapters 6 and 7 is presented below. The format of the questions has been modified to enhance readability. The visual aids used are also included.

Introducción y Bienvenida.
El cambio climático es un reto que requiere el esfuerzo de todos para mitigarlo. El objetivo de esta encuesta es evaluar el potencial de financiamiento de proyectos de captura de carbono en bosques para mitigar el cambio climático en México

Sabemos que no todas las personas están familiarizadas con este tema. Por eso antes de iniciar la encuesta le presentaremos información general sobre el cambio climático, el potencial de los bosques para mitigar el cambio climático y los proyectos de captura de carbono.

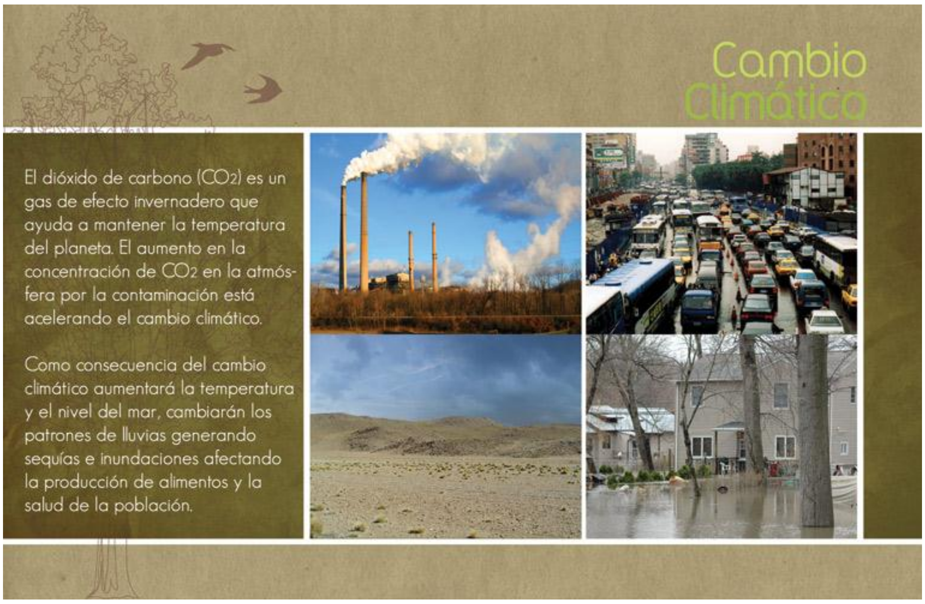
El tiempo estimado para contestar toda la encuesta es de 15 minutos.

Esta encuesta es llevada a cabo con fines académicos y es completamente ANÓNIMA y CONFIDENCIAL.

Si tiene cualquier duda o comentario respecto a este estudio por favor comuníquese al correo ambientaliteso@gmail.com o al ITESO al teléfono (33)36693510(Ingeniería Ambiental).

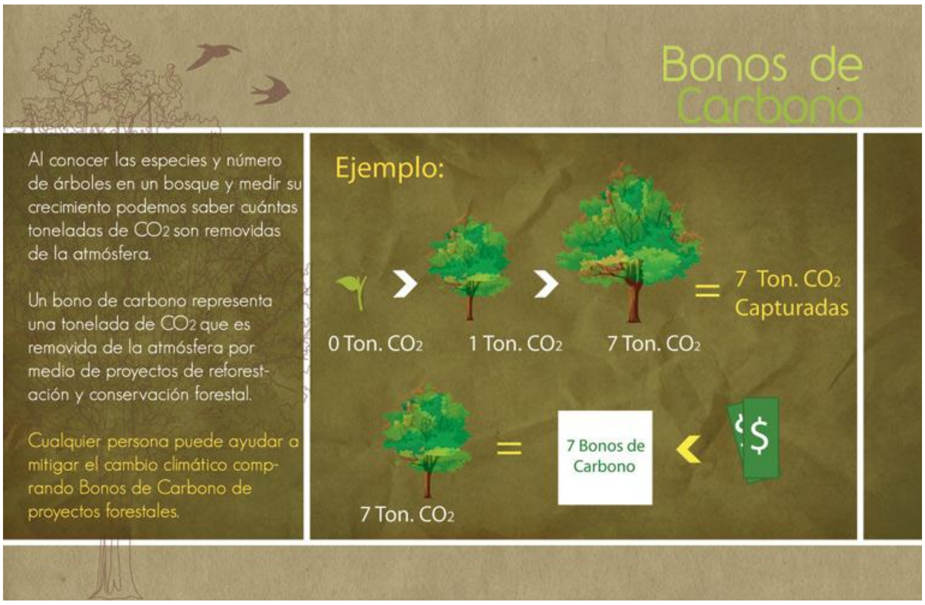
Estudio elaborado por: ITESO, University of Kent, CIGA UNAM, UNIVERSITY OF TWENTE.

Con apoyo de: DARWIN INITIATIVE, CONACYT, SEP SECRETARÍA DE EDUCACIÓN PÚBLICA




Bosques y Mitigación del Cambio Climático
Para mitigar el cambio climático es necesario contaminar menos y remover el exceso de CO_2 del aire; los bosques mitigan el cambio climático porque remueven el CO_2 de la atmósfera y lo almacenan en la vegetación y el suelo. Este proceso se llama "captura de carbono"; así se genera el oxígeno que respiramos.
Es necesario un esfuerzo permanente para conservar los bosques pues los incendios y la deforestación hacen que estos beneficios se pierdan, por esta razón se están desarrollando en todo el mundo "Proyectos de Captura de Carbono".
CO_2
O_2
C
Carbono en vegetación y suelo


Proyectos de Captura de Carbono
Para impulsar la captura de carbono, gobiernos, empresas y ciudadanos pueden pagar a campesinos y propietarios que realicen proyectos de reforestación y conservación en sus bosques.
El pago a los propietarios y campesinos se hace por cada tonelada de CO_2 que es removida de la atmósfera, la cual recibe el nombre de "bono de carbono".



Ejemplos de Proyectos de Captura de Carbono en México
Actualmente ya se desarrollan proyectos de captura de carbono en México. Algunos ejemplos son:
- Proyecto Plan Vivo, Scolel Té (Árbol que crece), coordinado por la ONG AMBIO.
- Programa Carbono Neutral, coordinado por la ONG Reforestamos México A.C.
- Proyecto Neutralízate, coordinado por PRONATURA A.C.

Estos proyectos se desarrollan principalmente en el sureste de México (Chiapas y Oaxaca).

Investigación
En esta encuesta nos gustaría saber si usted compraría o no bonos de carbono de proyectos de captura de carbono que se podrían desarrollar en otras zonas de México para mitigar el cambio climático.

Para esto le pedimos considerar la siguiente situación:

Por favor considere la siguiente situación hipotética para fines de esta investigación.

Nota: En cada reserva existen otros tipos de vegetación (e.g. bosque tropical, bosque de niebla), por favor considere que en este caso solo se trabajaría en los bosques de pino-encino.

Instrucciones
Nos gustaría saber si usted compraría bonos de carbono o no, y en su caso cuántos y de cuál proyecto.

Le haremos seis preguntas en las cuales le presentaremos dos opciones de compra (Opciones B y C) y una opción en caso de que usted no desee comprar bonos de carbono (Opción A). A continuación ponemos un ejemplo de las opciones que le presentaremos en las preguntas:

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$2,300	5 ton CO_2	La Michilía, Durango	
C	$1,700	5 ton CO_2	El Cielo, Tamaulipas	

En cada opción se presenta el costo total a pagar, la cantidad de bonos de carbono que usted compraría y la ubicación del proyecto.

En cada una de las opciones la cantidad a pagar cambia porque hay muchos factores que pueden incidir en el costo en cada sitio (por ejemplo: clima, tipo de suelo, mano de obra necesaria, etc.). Por este motivo le plantearemos diferentes cantidades para reflejar la variedad de proyectos que podrían desarrollarse. También incluimos varias cantidades de bonos de carbono a comprar para darle diferentes opciones para mitigar el cambio climático.

La forma de pago sería por medio de un PAGO ÚNICO deducible de impuestos y se pagaría directamente a la asociación civil. Usted obtendría un recibo deducible de impuestos y un certificado indicando los bonos de carbono comprados y el lugar donde se desarrolla el proyecto.

Le pedimos que en cada pregunta por favor elija aquella opción que usted compraría; usted puede elegir no comprar (Opción A). Por favor considere el dinero que debe gastar en otras cosas para tomar su decisión.

1. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$2,300	19 ton CO_2	La Primavera, Jalisco	
C	$1,000	9 ton CO_2	La Michilía, Durango	

2. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$2,300	5 ton CO_2	La Michilía, Durango	
C	$1,700	5 ton CO_2	El Cielo, Tamaulipas	

3. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$650	2 ton CO_2	La Michilía, Durango	
C	$1,700	9 ton CO_2	La Primavera, Jalisco	

4. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$1,000	19 ton CO_2	La Primavera, Jalisco	
C	$300	2 ton CO_2	El Cielo, Tamaulipas	

5. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$300	9 ton CO_2	La Primavera, Jalisco	
C	$1,000	19 ton CO_2	El Cielo, Tamaulipas	

6. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$1,000	2 ton CO_2	El Cielo, Tamaulipas	
C	$650	5 ton CO_2	La Michilía, Durango	

Version 2 of the Quationnaire

1. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$2,300	9 ton CO_2	El Cielo, Tamaulipas	
C	$1,700	2 ton CO_2	La Primavera, Jalisco	

2. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$650	19 ton CO_2	La Michilía, Durango	
C	$1,000	9 ton CO_2	El Cielo, Tamaulipas	

3. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$300	5 ton CO_2	La Primavera, Jalisco	
C	$1,700	19 ton CO_2	El Cielo, Tamaulipas	

4. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$1,700	5 ton CO_2	La Michilía, Durango	
C	$1,000	2 ton CO_2	La Primavera, Jalisco	

5. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$300	9 ton CO_2	La Michilía, Durango	
C	$650	2 ton CO_2	La Primavera, Jalisco	

6. Suponga que A, B y C son las únicas opciones. ¿Cuántos bonos compraría para mitigar el cambio climático?

Opción	Total a Pagar	Bonos de Carbono a comprar	Ubicación del Proyecto	Yo Elijo
A	Nada	-	-	
B	$2,300	19 ton CO_2	El Cielo, Tamaulipas	
C	$1,000	5 ton CO_2	La Michilía, Durango	

Pregunta Complementarias

7. En las preguntas 1 a 6 ¿Cuál fue el factor más importante para tomar sus decisiones? (Por favor elija una):
___El Costo Total.
___Número de toneladas de CO2.
___El Lugar del Proyecto (Por favor especifíque cual)___________

8. En su opinión las preguntas sobre la compra de bonos de carbono son:
___ Claras
___ Poco Claras
___ Confusas

9. Si las preguntas le parecieron confusas, nos podría por favor indicar que parte no quedó clara:

10. Si se creara un proyecto de captura de carbono en estas Reservas, usted:
___ Seguramente compraría bonos de carbono
___ Probablemente compraría bonos de carbono
___ Probablemente no compraría bonos de carbono
___ Seguramente no compraría bonos de carbono

11. ¿Cree usted que un proyecto de captura de carbono y la venta de bonos de carbono ayudará a conservar y restaurar las Reservas de la Biósfera propuestas?
___ Sí
___ No

12. Si contestó “No” a la pregunta anterior ¿Nos podría por favor indicar por qué? ¿Cuál sería una mejor opción?

13. ¿Preferiría usted apoyar un proyecto de reforestación/conservación en otra zona que no sea la Michilía, La Primavera o el Cielo?
___ No ___ Sí, Por favor especifíque cual. ___________

14. Para usted, ¿Cuál es la razón principal por la que SI COMPRARÍA bonos de carbono de proyectos forestales?

15. Para usted, ¿Cuál es la razón principal por la que NO COMPRARÍA bonos de carbono de proyectos forestales?

16. ¿Por qué compraría bonos de carbono para apoyar la conservación de un proyecto en la Reserva de la Biósfera de La Primavera/La Michilía/El Cielo/Cerro del Ajusco? (Seleccionar la opción local según el sitio en el aque se aplica la encuesta)

17. ¿Cuál es su opinión respecto a cada una de las siguientes afirmaciones? Por favor elija una opción para cada una.

	SI estoy de acuerdo	NO estoy de acuerdo
a. No compraré bonos de carbono porque yo ya cuido el medio ambiente de otras formas.		
b. No compraré bonos de carbono porque no tendré ningún beneficio.		
c. Estos proyectos traerán beneficios a largo plazo así que voy a comprar bonos de carbono ahora.		
d. Compraré bonos de carbono porque es mi responsabilidad compensar la contaminación que produzco con mi estilo de vida.		

18. ¿Alguna vez ha calculado su "huella de carbono"?
La "huella de carbono" estima cuantas toneladas de CO_2 genera con su estilo de vida.
___ Sí ___ No

19. ¿Ha participado en campañas de reforestación?
___ Sí ___ No

20. ¿Ha visitado alguna vez alguna de estas Reservas (La Michilía, La Primavera, El Cielo)?
___ No ___ Sí (Por favor indique cual(es))____________

21. ¿Hace usted donaciones a asociaciones ambientales o ecologistas?:
___ Sí ___ No

22. ¿Ha comprado bonos de carbono de proyectos forestales anteriormente?
___ No ___ í (recuerda el lugar, la cantidad de bonos y precio que pagó?) _____________

Información General
Queremos asegurarnos que en la encuesta participan personas que representen a los habitantes de diferentes partes de México. Por favor conteste las siguientes preguntas.

23. ¿En cuál Estado de la República Mexicana vive actualmente?
___ Durango
___ Jalisco
___ Tamaulipas
___ Otro (por favor especifíque)

24. ¿En cuál municipio/delegación vive?: ___

25. ¿En cuál Estado de la República Mexicana nació?
___ Durango
___ Jalisco
___ Tamaulipas
___ Otro (por favor especifíque) ___

26. ¿Cuánto tiempo tiene viviendo en su ciudad actual? (años)
27. Año de Nacimiento. __________
28. Sexo: ___ Masculino ___ Femenino
29. Estado Civil: ___ Soltero(a) ___ Casado(a)
30. ¿Es usted el jefe(a) de su hogar? ___ Sí ___ No
31. Tamaño de su hogar. ¿Cuántas personas viven en su casa?:____________
32. ¿Tiene hijos(as)? ___ Sí ___ No

33. Por favor indique el nivel máximo de escolaridad que ha alcanzado o está estudiando hasta el momento:
___ Primaria
___ Secundaria

___ Preparatoria
___ Carrera Técnica
___ Licenciatura/Ingeniería
___ Maestría/Doctorado ___ Otro (especifique) ___

34. Por favor indique su situación laboral actual (marque todas las que apliquen):
___ Estudiante
___ Empleado (de confianza, no sindicalizado)
___ Empleado (sindicalizado)
___ Responsable del Hogar (Ama(o) de casa).
___ Empresario (Negocio Propio, Asociado)
___ Retirado
___ Desempleado

35. Por favor indique el sector de actividad al cual pertenece su centro de trabajo o negocio (por favor elija una opción):
___ Desempleado
___ Agropecuario, Forestal, Minería.
___ Construcción, Inmobiliario y de Alquiler
___ Industria, Comercio, Transporte
___ Educación, Investigación
___ Salud
___ Gobierno y Sector Público
___ Otros Servicios
___ Industria/Servicios relacionados con la ecología y el medio ambiente
___ Otro o Estudiante (Por favor especifique)

36. ¿Cuál de las siguientes categorías corresponde al ingreso MENSUAL TOTAL de su hogar considerando todas las personas que viven en su hogar? Por favor marque una:
___ No tenemos ingresos
___ Menos de $2,000
___ de $2,000 a $4,000
___ de $4,000 a $8,000
___ de $8,000 a $15,000
___ de $15,000 a $30,000
___ más de $30,000

Este es el final de la encuesta! !Muchas gracias por su tiempo y su participación!

Le recordamos que esta encuesta es llevada a cabo con fines académicos y es completamente CONFIDENCIAL y ANÓNIMA.

Si tiene cualquier duda o comentario respecto a este estudio por favor comuníquese al correo ambientaliteso@gmail.com o al ITESO al teléfono (33)36693510 (Ingeniería Ambiental).
37. ¿Le gustaría estar en contacto con el equipo de investigación y recibir los resultados de la investigación? Usted puede escribirnos al correo mostrado arriba o escribir su correo electrónico para comunicarnos con usted:

38. ¿Cómo se enteró de la encuesta?

39. Comentarios. Agradeceremos mucho cualquier comentario que nos pueda hacer sobre la encuesta y este tipo de proyectos. Gracias.

Muchas gracias!

Estudio elaborado por:

Con apoyo de:

Annex III: Questionnaire applied to landowners/ejidos.

The questionnaire used to evaluate the potential provision of forest environmental services as described in Chapter 8 is presented below. The format of the questions has been modified to enhance readability. The visual aids used are also included.

___Ejido ___Sucesor ____ Prop. Privada

Encuestador_______________ Lugar, Fecha,____________________________ No. Id.___________

Esta encuesta es realizada con fines ACADÉMICOS, es ANÓNIMA y CONFIDENCIAL.

El objetivo es saber CÓMO APOYAR A LOS PROPIETARIOS A CONSERVAR LOS BOSQUES Y PROMOVER EL DESARROLLO RURAL.

1¿Tiene terrenos con bosque? ____Sí ____No

2 Qué tipo de bosque/árboles tiene su terreno: ___Pinos___Encinos___Otros:_______________

3 El área de bosque que tiene está en:
____ Terreno plano ____ Montaña

4 ¿Cuántas hectáreas de terreno tiene? de:
_______ Bosque o Monte
_______ Cultivos: ¿Cuáles?_______________
_______ Pastizal: Tiene ganado? ___Si ___No
_______ Otro.________________

5 Las actividades que hace en sus terrenos son para: _____ Autoconsumo ___ Venta Comercial.

6 ¿Qué actividades espera estará realizando en diez años en su terreno forestal?

Proporcionar el Tarjetón. Mensajes Clave: Antes de seguir vamos a presentar esta información.

Los bosques generan muchos beneficios, pero por la deforestación e incendios se están perdiendo. Actualmente hay proyectos para ayudar a los propietarios y ejidatarios que quieran cuidar los bosques.

Imagine que se hará una Asociación Civil, Bosques de México para apoyar a la conservación forestal en la zona donde está su terreno.

Los propietarios que quieran participar recibirán un pago anual por hectárea y tendrían apoyos para salud, educación, empleo o proyectos productivos por la cantidad de años que dure el proyecto de conservación.

A cambio el compromiso de quienes quieran participar será conservar el bosque, evitar los incendios y la tala en la zona que se elija para el proyecto.

1. Los Bosques y sus Beneficios.

Los bosques generan muchos beneficios que son disfrutados local y mundialmente:
Ayudan a que haya agua en los pozos; controlan las inundaciones y deslaves; regulan el clima; son la casa de plantas y animales; crean el paisaje y son lugares de recreación.

Sin embargo debido al desmonte, la deforestación y los incendios forestales se han perdido muchos bosques y con ellos se pierden los beneficios que generan.

Para resolver este problema en muchos países se están haciendo proyectos para cuidar los bosques. En estos proyectos el gobierno, empresas o asociaciones civiles apoyan a los propietarios que quieren cuidar sus bosques.

2. Propuesta: Conservación Forestal.

Queremos saber si a usted le gustaría proteger el bosque y participar en estos proyectos.
Le pedimos que considere la siguiente situación:

Se creará la asociación civil Bosques de México A.C. que recibirá aportaciones de empresas y gente que quiera ayudar a cuidar los bosques. La asociación civil invitará a propietarios y ejidatarios que quieran cuidar sus bosques para ofrecerle algunos de los siguientes beneficios:

- Un pago anual por hectárea de bosque conservado.
- Mejorar los servicios de salud y educación en la región del proyecto .
- Promover el empleo y proyectos productivos entre los participantes.

3. Descripción de Apoyos para los Participantes

Pago en Efectivo: Pago de una cantidad anual por hectárea para cubrir los costos necesarios para conservar el bosque.

Salud y Educación: Pago de cuotas de seguro popular de los participantes. Contratación de un maestro de secundaria o preparatoria para dar clases a los participantes y sus familiares.

Empleo y Proyectos Productivos: Publicación de ofertas de trabajo de empresas de la región. Apoyo de especialistas para evaluar proyectos productivos y ayudar a conseguir fondos.

Estos beneficios se tendrían por el tiempo que dure el proyecto de conservación forestal.

4. Compromisos.

Los propietarios de terrenos forestales pueden participar en estos proyectos de conservación. Los principales compromisos que asumirían al participar en el proyecto son los siguientes:

- Conservar, restaurar y en su caso reforestar el área designada.
- Prevenir y combatir incendios forestales.
- Hacer monitoreo e inventarios forestales.
- Controlar las plagas.
- Evitar el ingreso de ganado a la zona.
- Prohibir la caza y tala ilegal.

Las actividades, compromisos y responsabilidades de ambas partes quedarían plasmados en un convenio de colaboración. En ningún momento el participante o ejido pierden la propiedad del terreno.

A continuación le vamos a presentar varias opciones de cómo se puede realizar el proyecto.
(Proporcionar una por una las preguntas de beneficios del proyecto.)

1.1 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

1.1	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$415	9 años	Salud/Educación	
B	$2,230	5 años	Ninguno	
C	Ninguna			

1.2 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

1.2	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$1,580	17 años	Ninguno	
B	$960	5 años	Empleo/Proy.Productivos	
C	Ninguna			

1.3 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

1.3	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$415	17 años	Empleo/Proy.Productivos	
B	$960	5 años	Salud/Educación	
C	Ninguna			

1.4 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

1.4	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$415	9 años	Empleo/Proy.Productivos	
B	$1,580	9 años	Ninguno	
C	Ninguna			

1.5 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

1.5	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$2,230	9 años	Empleo/Proy.Productivos	
B	$415	17 años	Empleo/Proy.Productivos	
C	Ninguna			

1.6 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

1.6	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$415	9 años	Salud/Educación	
B	$1,580	5 años	Salud/Educación	
C	Ninguna			

Version 2 of the Quationnaire

2.1 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

2.1	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$2,230	17 años	Salud/Educación	
B	$2,230	9 años	Empleo/ProyectosProductivos	
C	Ninguna			

2.2 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

2.2	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$1,580	5 años	Salud/Educación	
B	$960	17 años	Ninguno	
C	Ninguna			

2.3 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

2.3	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$2,230	5 años	Ninguno	
B	$960	17 años	Ninguno	
C	Ninguna			

2.4 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

2.4	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$1,580	17 años	Ninguno	
B	$960	5 años	Empleo/ProyectosProductivos	
C	Ninguna			

2.5 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

2.5	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$415	17 años	Salud/Educación	
B	$960	5 años	Empleo/ProyectosProductivos	
C	Ninguna			

2.6 ¿Cuál opción preferiría para implementar el proyecto? Por favor maque con una X su opción preferida.

2.6	Pago Anual por Hectárea	Duración Convenio	Otros Beneficios	Prefiero
A	$2,230	9 años	Ninguno	
B	$1,580	9 años	Salud/Educación	
C	Ninguna			

PREGUNTAS COMPLEMENTARIAS

13. En su opinión, las preguntas anteriores son:
____ Claras
____ Poco Claras
____ Confusas

14.¿Cuáles fueron los dos factores más importantes que consideró al contestar? (Numere 1 y 2, siendo 1 el más importante):
____ El Pago
____ Número de Años.
____ Salud/Educación
____ Empleo/Proyectos Productivos

15. ¿Cuál sería la razón principal por la que SI participaría para conservar el bosque?

16. ¿Cuál sería la razón principal por la que NO participaría para conservar el bosque?

17. Por favor indique si está de acuerdo o no.

	SI	NO
a.Participaré para mejorar el ambiente para las futuras generaciones.		
b.Participaré porque es responsabilidad de todos mejorar el medio ambiente.		

18. ¿Si se realiza este proyecto, participaría?:
___ Sí. ___ Tal vez Sí. ___ Tal vez No ___ No.

19. ¿Cuántas hectáreas metería al proyecto?: ___________________________________

19.a ¿Reforestaría parte de su parcela para entrar al proyecto? (<u>En el caso de sucesores, pregunte sí haría estas actividades en caso de recibir el título</u>).
Reforestación Total. __No __ Sí
Numero Hectáreas y uso actual_________________

Reforestación de Perímetro (Cortinas cortaviento)
__No __ Sí
Numero Hectáreas y uso actual_________________

*En que caso si haría la reforestaciones arriba mencionadas? (si se ofrece…?)
____

20. ¿Le gustaría que las áreas de <u>uso común</u> de su ejido se integren al proyecto?
___ Sí
___ Tal vez sí
___ Tal vez no.
___ No
___ No soy ejidatario/No puedo votar.

INFORMACIÓN DEL TERRENO

21. ¿Dónde está su terreno? (Ejido o municipio):_____________________________
22. Está dentro del área protegida de La Primavera ___Sí ___No ___ Parcialmente
23. ¿Desde cuándo adquirió el terreno con bosque? ____________________

24. Actualmente ¿Cuál es el precio aproximado de los terrenos en esa zona?
Con Bosque _________________ pesos 1 hectárea
Sin Bosque _________________ pesos 1 hectárea

25. ¿Cuánto tiempo tarda para llegar al terreno desde su casa?: ____________horas
26 En qué medio de transporte__________________
27. Actualmente ¿Qué beneficios recibe del bosque?
____ Madera y leña.
____ Forraje y área para Agostadero

____ Área de día de campo
____ Animales para comer
____ Aire limpio
____ Manantiales, Ríos y Pozos
____ Otro:________________________

28. Actualmente qué actividades realiza para cuidar el bosque:
___ Tengo brechas cortafuego.
___ Puse reja de alambre alrededor
___ Controlo las plagas en árboles
___ Le doy mantenimiento a caminos
___ Participo en la brigada contra incendios.
___ Tengo plan de manejo forestal autorizado.
___ Pago un velador/jornales para estas tareas.
___ Otro:_______________________

29. ¿Ha participado en el programa de pago por servicios ambientales de CONAFOR?
____ Si
____ No
____ Envié solicitud pero no me dieron recursos.

30. ¿Es miembro del comisariado ejidal?:
___ Si
___ No ahora, pero sí en el pasado
___ No
___ No Aplica

INFORMACIÓN INDIVIDUAL
31. Código Postal de su domicilio:_______________
32. Lugar de Nacimiento:_____________________
33. Tiempo viviendo en localidad actual: _____años
34. Edad______________
35. Sexo: ___Masc. ___Fem.
36. __Soltero(a) ___Casado(a) ___ Viudo(a)
37. Es usted el jefe(a) de su hogar:___ Si ___No
38. ¿Cuántas personas habitan su casa?_______
39. Tiene hijos(as): ____Si ____No
40. ¿Cuántos autos/camionetas tiene?_________

41. ¿Cuál es el grado de escolaridad que ha alcanzado
o está estudiando hasta ahora?:
___ Primaria ___ Secundaria
___ Preparatoria ___ Carrera Técnica
___ Licenciatura ___ Maestría/Doctorado
___ Ninguno ___Otro (Indique):______

42. Por favor indique sus ocupaciones actuales:
___ Actividad Agropecuaria
___ Estudiante
___ Empleado de Empresa
___ Responsable del Hogar (Ama(o) de casa).
___ Empresario (Negocio Propio, Asociado)
___ Retirado
___ Desempleado
___ Recibo Rentas
___ Recibo Remesas

43. ¿Cuál es el ingreso TOTAL de las personas
que viven en su hogar por mes?:
___ Menos de $4,000
___de $4,000 a $8,000

___ de $8,000 a $15,000
___ más de $15,000

MUCHAS GRACIAS!

Comentarios:

Muchas gracias! Para cualquier comentario comuníquese a ambientaliteso@gmail.com al ITESO al teléfono (33)36693510.

Estudio elaborado por:

Con apoyo de:

Summary

This work makes a multidisciplinary analysis of the potential of market-based mechanisms in the provision of forest carbon services based on local demand in the context of climate change mitigation. The analysis contrasts, from the perspective of an emerging economy (Mexico), the possibilities of local markets versus the global markets mechanisms being developed under the United Nations Framework Convention on Climate Change (UNFCCC).

Forest carbon services can mitigate climate change through two principal processes: firstly, through reduction of carbon dioxide emissions resulting from deforestation and forest degradation; and secondly, through removal of atmospheric carbon dioxide and its storage in biomass and forest soil by enhancement and/or expansion of forests.

Market mechanisms can be viewed as incentive-based policy options that enable different actors (both users and providers) to meet and settle agreements that determine the level of provision of specific goods and services. In our situation, the services are related to the extent to which landowners and communities adopt forest management and conservation practices that generate a myriad of benefits ranging from climate change mitigation to conservation of biodiversity and of the landscape beauty. The basic rationale behind the schemes is that forest managers (i.e. communities or landowners) can receive compensation for undertaking actions that increase forest carbon services. Their performance is measured in terms of carbon benefits (reduced emissions or carbon removals) that are accounted for by comparing the results of their actual activities against a baseline scenario. Once the benefits are quantified, often in the form of carbon credits, providers can negotiate compensation payments from buyers desiring to offset their emissions elsewhere. However, such markets need to be created. Currently, there are two types of markets depending on how the demand for carbon credits is created: compliance and voluntary markets. Additionally, there are other incentive-based policy options, such as Payments for Environmental Services (PES), that also target the implementation of forest conservation activities in developing countries (Chapter 2). In this research, the potential for local market mechanisms is studied on the basis of the model offered by the voluntary carbon markets. The scale of a local market is determined by coexistence of potential buyers and providers of the environmental services within the same geographical context (e.g. jurisdiction or region).

This study includes an analysis of various elements of market mechanisms related to environmental values using an area of Mexico as a case study. Specifically, the study addresses the Biosphere Reserve of La Primavera in the state of Jalisco located in the west of Mexico, and the involvement of the citizens of Guadalajara, the capital of Jalisco. The components that integrate this research are the quantification and measurement of forest carbon services, their potential provision by landowners and communities, the valuation and potential for financing when targeting local demand, and the characteristics of an institutional framework that could be designed and used as part of a market mechanism.

The principal methodological approach used is based on environmental economics, and involves the valuation of forest carbon services by users and providers at the local level. However, such an analysis requires additional information to define the scale of the carbon services that could be provided by the oak-pine forests in México. For this, the research has also included forest inventory techniques to estimate the provision of forest carbon services. The third approach included in the research is related to the definition of a framework for the valuation of carbon benefits under the international programme for the reduction of emissions from deforestation and forest degradation being developed under the UNFCCC (REDD+). The

potential and implications of a local market mechanism for forest carbon services are explored from two perspectives. The first approach relies on a standard comparison of the potential demand and provision of forest carbon services. If the valuation by potential buyers is higher than the willingness of landowners and communities to provide them, then there is room for negotiated agreements for the provision of forest carbon services compensated through mechanisms based on local financing. Usually the exchanges made in market-based mechanisms aim to value natural capital and internalize this value in economic transactions. The second approach for evaluating the potential of local markets to deliver forest carbon services uses the livelihoods approach to development (Carney, 1998), which broadens the scenarios under which negotiations can take place. Using the livelihoods approach makes it possible to depict potential exchanges that also have the possibility to support local sustainable development through in-kind compensation targeting local human, productive and social capitals (Chapters 2 and 3).

At the beginning of this research, a multi-stakeholder participatory workshop was held in Guadalajara, Mexico, to identify the main causes of deforestation and forest degradation in Mexico, and to identify the knowledge gaps associated with the quantification, provision, demand and the institutional framework of local markets for forest services. These discussions helped to identify specific research questions for investigation and to identify barriers and opportunities for the implementation of market-based mechanisms in Mexico (Chapter 2). From this analysis, two possiblities for implementation of this type of policy in Mexico were identified. The first is in protected areas where landowners and communities are not usually compensated for limitations on conventional economically productive activities that require conversion of forests to other land uses (e.g. agriculture, grazing, housing). The second were the dry forests where the benefits from sustainable forest management and the yields from alternative land uses are usually too low for landowners/communities to be interested since the social cost associated with deforestation and forest degradation would be higher, making these land uses/covers worth preserving from an economic perspective. Both sets of conditions were present in La Primavera, thus providing the possibility to study the potential of a local market. In this context, the case study serves to provide insights into the use of such policy options for climate change mitigation, biodiversity conservation and local sustainable development. The quantification of the forest carbon services that can be provided by La Primavera can be compared with the GHG emissions produced in Guadalajara in order to assess the contribution that such actions could make towards a sustainable level of emissions. In targeting the implementation of forest conservation and enhancement efforts in the Biosphere Reserve and the unprotected wildlife corridors that still connect La Primavera to other forested areas, it becomes possible to assess how market mechanisms can contribute to biodiversity conservation.

Four rounds of fieldwork and data collection were undertaken to produce the results presented here. First, a forest inventory was carried out in the mixed oak-pine forest of La Primavera in order to estimate the level of carbon stocks in the standing biomass of trees; and this information was then used to estimate the potential provision of forest carbon services in La Primavera. The inventory was stratified by canopy cover to account for the effect of forest degradation (Chapters 4 and 5). Second, a survey, using choice experiment methodology for environmental valuation, was carried out among citizens of Guadalajara to determine the valuation of forest carbon services and the effect of geographical location. The choice experiment proposed to the participants that they consider the voluntary purchase of carbon offsets at varying costs from projects developed in different parts of Mexico. The possibility for carbon sequestration in order to mitigate climate change in La Primavera was shown in competition with two Biosphere Reserves located in the states of Durango and Tamaulipas; and three survey application modes were tested to assess their influence on the results (i.e. two online and one in-person methods) (Chapter 6). In a third round of fieldwork, the same questionnaire was used online with citizens from the states of Durango and Tamaulipas and with citizens from Jalisco but outside of Guadalajara. In the context of the experiment, the respondents from these regions, were also faced with the question of choosing between local or non-local options for absorbing carbon in forests. The survey was also applied among citizens of the metropolitan area of Mexico City for which there were no local offsets on offer (Chapter 7). For the fourth round of fieldwork, a choice experiment was developed and applied among landowners and communities in La Primavera and its wildlife corridors. The survey investigated their willingness to participate in PES-type programmes for the conservation and enhancement of forested areas in which participants could receive cash and in-kind compensation when joining the project. These in-kind benefits from participation were related to interventions that improved local conditions related to health, education, employment and productive projects (Chapter 8).

The potential development of projects targeting carbon markets within the context of REDD+ is addressed in Chapter 9. This research puts forward an option for the sharing of benefits under REDD+. Here, a differentiated attribution of the benefits and incentives for reducing emissions and for enhancing the carbon in forests is proposed. Under this framework, projects resulting in carbon enhancements in forests could be more easily and independently implemented by private actors (i.e. communities, firms and individuals) and be financed through market-based mechanisms (local or global). Conversely, emission reductions would be more easily credited to public actors at the national or subnational level to address a series of issues such as the need to ensure the integrity of carbon accounting and compliance with national performance targets (Chapter 9).

Results indicate that the valuation that the citizens of Guadalajara give to La Primavera and its carbon services is sufficient to finance activities to mitigate climate change locally. A supply-side analysis shows that implementation prospects increase when other benefits are included since these reduce the need for financial compensation. However, the implementation potential is also geography related, and the results indicate that there would be tensions and less participation in voluntary schemes among communities and landowners located in the areas closest to the city of Guadalajara. This is because of the high opportunity costs in the peri-urban area where the demand for housing boosts land prices (Chapter 8). In these areas, conserving forest cover and the associated benefits will depend heavily on the capacity of governmental offices to enforce land use regulations and prevent land conversion. Aside from this localised effect, the implementation prospects are promising since the potential production of carbon services, and the carbon prices that could paid by local users, would be sufficient to match the willingness to accept expressed by members of communities and landowners. The potential for local financing is also higher than the reference payment set by the PES programme run by the national government. The potential to generate agreements for the provision of forest carbon services at the local level is also evidenced by the development of an early implementation project, based on this research, in the study area (Chapters 8 and 10).

The results show that including a consideration of local co-benefits can produce a higher environmental valuation among the potential buyers in market mechanisms, thus increasing their willingness to pay. Likewise, the inclusion of in-kind compensation that enhances local conditions related to human and productive capital among providers can help reduce the financial requirements in incentive-based mechanisms. This also creates an opportunity to strengthen social capital through bargaining and negotiation process between local users and producers of environmental services. If everything else remains constant, local market mechanisms, by increasing the users' valuations and reducing the supply costs, will implement a higher level of climate change mitigation actions than non-local options (e.g. options in locations away from the people where the valuation would be lower). Additionally, local voluntary markets offer actors the opportunity to meet and to reach agreements within a shared cultural, economic and institutional framework. This can reduce the transaction costs associated with monitoring and verifying the implementation outcomes, and enable contracts to be framed within a shared legal framework that provides greater certainty over the process to be followed in cases of non-compliance. The reduced transaction costs of a local scheme, compared to a global market, also impacts positively in terms of the viable scale of implementation of climate change mitigation actions. In the case described here, between the Biosphere Reserve of La Primavera and the city of Guadalajara, the building up of implementation activities, from the local to the regional, then national and global levels, enables the generation of co-benefits that increase welfare which would not be guaranteed if the mitigation actions were implemented in the reverse order.

Based on the results presented here, specific recommendations are made for an institutional framework for local market mechanisms. Implementation can be facilitated if a framework for a local market is able to define the management practices and identify the areas where activities can maximize local co-benefits and welfare. The bargaining between suppliers and buyers/users will be enhanced if the property rights over the environmental services, and the responsibility for their use, are clearly defined as part of the institutional framework. Interestingly, even if property rights are not perfectly defined by formal rules, generating information on the provision and use of the environmental services can still help to mobilize actors sharing a common view of environmental property rights (i.e. environmental responsibility). The inclusion of flexible mechanisms that enable the use of mixed incentives (e.g. non-cash compensation) as part of this bargaining process can help to engage providers, reduce the mitigation cost and fortify social capital. A problem that often arises from the provision of public goods is free-riding (e.g. Wohar, 1988). However, as shown in the case of La Primavera, it is not necessary for all the population to participate in the provision of the public goods. The provision of climate-related public benefits and other local co-benefits can be realised if about 1% of the population of Guadalajara participates. Implementation prospects can be further improved if the scheme promotes cooperation, solidarity and subsidiarity among the relatively few actors required, since it is the participation of a few actors that generates benefits for all.

Taking a more general view, the results indicate a consistent demand-side preference for local project locations when such options are available. The questionnaire responses also show that, if citizens are not offered a local option, they then prefer the most cost-efficient option, as would be expected from market economic theory (Chapter 7). This indicates that when citizens are faced with selecting forest mitigation options they invoke a dual decision-making process that includes the minimization of expenditure, as expected from economic theory, and the maximization of benefits when local action is possible. Although the effect of local co-benefits on climate change mitigation actions has been identified before as a relevant element in the general design of climate policy (e.g. Pearce, 2000), this aspect had not been included in the literature on the valuation of forest carbon services or in the assessment of potential demand in market mechanisms, both topics that have scarcely been investigated. This societal preference for climate mitigation in local forests and the production of co-benefits reflects a 'yes-in-my-backyard' effect that can help in the design of appropriate institutional frameworks that incorporate local welfare in the valuation of forest carbon services.

Resumen

Este trabajo analiza desde un punto de vista multidisciplinario el potencial de desarrollo de mecanismos de mercado para la provisión de servicios forestales de carbono basados en demanda local en el contexto de mitigación del cambio climático. Este análisis sirve para contrastar desde el punto de vista de un país con una economía emergente (México), las posibilidades de desarrollar mercados locales en oposición con los mecanismos globales de mercado desarrollados bajo la Convención Marco de las Naciones Unidas para el Cambio Climático (CMUNCC).

Los bosques pueden contribuir a mitigar cambio climático generando servicios ambientales de carbono por medio de dos procesos principales: primero, al disminuir las emisiones de dióxido de carbono producto de la deforestación y degradación forestal; y segundo, por medio de la remoción del dióxido de carbono atmosférico (captura o secuestro de carbono) y su almacenamiento en la biomasa y suelos forestales gracias al crecimiento forestal y expansión de áreas forestales (reforestación/forestación).

Los mecanismos de mercado son instrumentos de política pública que generan incentivos para que diferentes actores (en este caso usuarios y proveedores) negocien y lleguen a acuerdos para determinar el nivel de provisión de diferentes bienes y servicios. En este caso, la provisión de estos servicios se relaciona con el nivel al cual los propietarios de terrenos forestales y comunidades rurales están dispuestos a adoptar medidas de manejo forestal y conservación ambiental que generan diversos beneficios ambientales que van desde la mitigación del cambio climático, hasta la conservación de la biodiversidad y del paisaje.

El enfoque básico de estos esquemas es que los poseedores de terrenos forestales (p. e. propietarios y comunidades) que le den un manejo apropiado a los bosques de forma tal que aumentan la provisión de los servicios forestales de carbono, puedan recibir una compensación por el desarrollo de estas actividades. El desempeño en la implementación de estas medidas de mitigación del cambio climático normalmente se expresa como la cantidad de emisiones evitadas o toneladas de carbono capturado, y se contabilizan al comparar los resultados reales de implementación con un escenario de línea base. Una vez que estos beneficios son cuantificados, los proveedores pueden negociar la compensación por un pago con compradores que deseen neutralizar sus emisiones de gases de efecto invernadero. Estos compradores pueden estar localizados en cualquier lugar del mundo.

Es necesario crear estos mecanismos de mercado para permitir el encuentro entre proveedores y usuarios. Actualmente, existen dos tipos diferentes de mercados de carbono cuya diferencia es la forma como se estimula la demanda entre los usuarios/compradores: los mercados de cumplimiento legal y los mercados voluntarios. Además de los anteriores, otro grupo de políticas basadas en incentivos y mercados, los Pagos por Servicios Ambientales (PSA), también se enfocan en el desarrollo de actividades de conservación forestal; en el Capítulo 2 se describen las características generales de los mecanismos de mercado y los PSA. En este trabajo, el potencial para el desarrollo de mecanismos de mercado locales es estudiado desde la perspectiva ofrecida por el mercado voluntario de carbono. En este sentido, la escala *local* de un mercado está determinada por la coexistencia de los proveedores y usuarios de los servicios ambientales dentro del mismo contexto geográfico (p.e. jurisdicción o región).

Este estudio incluye el análisis de diferentes elementos que forman parte del diseño de los mecanismos de mercado y utiliza una región de México como área de estudio. Específicamente, se aborda la situación de la Reserva de la Biosfera Bosque La Primavera en el estado de Jalisco

en México como un área proveedora de servicios ambientales, y a la población de la ciudad de Guadalajara, la capital de Jalisco, a quienes se identifica como usuarios de los servicios ambientales. Los diferentes elementos en los que se divide esta investigación son la cuantificación y estimación de la magnitud de los servicios ambientales de carbono, el potencial y disposición a proveer estos servicios entre propietarios y comunidades, la valoración y potencial de financiamiento basados en la demanda local, y las características de un marco institucional que podría servir para el diseño de un mecanismo local de mercado.

El principal enfoque metodológico de este trabajo se basa en la economía ambiental e incluye la valoración que los usuarios y proveedores hacen de los servicios forestales de carbono a una escala local. Sin embargo, para realizar dicho análisis fue necesario generar información auxiliar que permita definir la escala y magnitud de los servicios forestales de carbono de los bosques mixtos de encino-pino en México. Por esta razón, la investigación también incluye trabajos de inventario forestal para estimar la magnitud de los servicios forestales de carbono. El tercer enfoque metodológico incluido corresponde a la definición del marco institucional para la valoración de los servicios de mitigación del cambio climático en el contexto del programa internacional para la reducción de emisiones de deforestación y degradación y la función de la conservación, la gestión sostenible de los bosques y el aumento de las reservas forestales de carbono en los países en desarrollo bajo la CMNUCC (REDD+).

El potencial y las implicaciones de un mecanismo de mercado local para los servicios forestales de carbono se evalúan desde dos perspectivas. El primer criterio se basa en la comparación estándar de la demanda y oferta potenciales de los servicios forestales de carbono. Si la valoración de los servicios entre los usuarios es mayor que el costo de provisión y la disposición de los propietarios y comunidades para generar estos servicios, entonces habrá un espacio para la negociación de acuerdos que aumenten la provisión de los servicios forestales de carbono vía la compensación por medio de mecanismos de mercado financiados localmente. Usualmente este tipo de intercambios en mecanismos de mercado tienen como objetivo darle un valor monetario al capital natural para internalizar su valor en las transacciones económicas. El segundo enfoque para evaluar el potencial de mecanismos locales en la provisión de servicios forestales de carbono se basa en el enfoque de los modos de vida sustentables para el desarrollo (Carney, 1998), que permite ampliar el escenario en el cual se realizan las negociaciones entre los participantes. Utilizando el enfoque en los modos de vida sustentable permite describir el potencial para negociaciones que también incluyan otras dimensiones del desarrollo local por medio de compensaciones en especie etiquetadas para intervenciones que incrementen los niveles locales relacionados con el capital natural, productivo y social (Capítulos 2 y 3).

Al principio de la investigación, se realizo un taller participativo con diferentes grupos interesados en la ciudad de Guadalajara, con el objetivo de identificar las principales causas de la deforestación y degradación forestal en México y para identificar las necesidades de información asociadas a la cuantificación, provisión, demanda y el marco institucional para un mercado de servicios forestales. Los diálogos y discusiones del taller sirvieron a su vez para identificar áreas específicas de investigación así como para las barreras y oportunidades para la implementación de mecanismos de mercado en México (Capitulo 2). A partir de este análisis, se identificaron dos casos en los que se el desarrollo de mecanismos de mercado tendría mejores prospectivas de implementación en México. La primera corresponde a las áreas naturales protegidas, donde los propietarios y comunidades normalmente no son compensados por las prohibiciones de los usos de suelo y actividades económicas convencionales que requieren la reconversión de bosques y selvas (p.e. agricultura, ganadería, urbanización). El segundo caso corresponde a bosques y selvas en ambientes secos donde los beneficios del manejo forestal sustentable y los rendimientos de las actividades económicas alternativas son bajos; en este caso los costos sociales por la perdida de los servicios ambientales al hacer un cambio de uso de suelo hacen que sea socialmente viable la conservación de estas zonas forestales desde un punto de vista económico. Estas dos condiciones están presentes en el caso de La Primavera por lo que la investigación refleja la prospectiva para el desarrollo de un mecanismo de mercado a nivel local.

En este contexto el caso de estudio provee una visión del potencial de este tipo de políticas para la mitigación del cambio climático, la conservación de la biodiversidad y el desarrollo local sustentable. La cuantificación de los servicios forestales de carbono que pueden ser provistos por La Primavera pueden compararse con las emisiones de gases de efecto invernadero generadas en Guadalajara para evaluar la contribución de estas estrategias en la mitigación del cambio climático buscando un nivel sustentable de emisiones. La contribución de estas políticas para la conservación de la biodiversidad se obtiene al enfocar los esfuerzos de la investigación y posible implementación en la Reserva de la Biosfera de La Primavera y sus corredores de fauna los cuales actualmente no están protegidos.

Los resultados presentados en este trabajo se basan en la información recolectada durante cuatro etapas de trabajo de campo:

- Primero, se desarrolló un inventario forestal en los bosques mixtos de encino-pino en La Primavera para generar un estimado del acervo de carbono en la biomasa arbórea; esta información fue utilizada para estimar la provisión de servicios ambientales forestales en La Primavera. El inventario fue estratificado por cobertura de copa para poder estudiar el efecto de la degradación forestal (Capítulos 4 y 5).
- Segundo, una encuesta basada en el método de valoración ambiental de modelación de elecciones, fue aplicada a ciudadanos de Guadalajara para conocer la valoración de los servicios forestales de carbono y como esta es afectada por la ubicación geográfica donde se realiza el proyecto de mitigación del cambio climático. La encuesta proponía a los participantes que consideraran la compra voluntaria de certificados de captura de carbono con diferentes precios de proyectos que podrían desarrollarse en diferentes partes del país. En la encuesta se mostraba la posibilidad de pagar para financiar actividades de mitigación del cambio climático en La Primavera en competencia con proyectos a desarrollarse en otras dos Reservas de la Biosfera ubicadas en los estados de Durango y Tamaulipas; tres métodos de aplicación de encuesta fueron evaluados para identificar cómo los diferentes métodos podrían afectar los resultados (i.e. dos métodos por internet y uno en persona) (Capitulo 6).
- En una tercera ronda de trabajo de campo, la misma encuesta fue aplicada a ciudadanos de Durango, Tamaulipas así como a ciudadanos de Jalisco incluyendo ciudades diferentes a Guadalajara. Al igual que los habitantes de Jalisco, los ciudadanos de Durango y Tamaulipas tuvieron que hacer decisiones considerando la mitigación del cambio climático en una Reserva local en competencia con otros sitios alternativos. La encuesta también fue aplicada a ciudadanos de la zona metropolitana de la ciudad de México para quienes el experimento no incluyo ninguna opción local (Capitulo 7).
- En la cuarta etapa, otra encuesta de modelación de elecciones fue aplicada entre propietarios y ejidatarios presentes en La Primavera y sus corredores de fauna. La encuesta estudio la disposición de los propietarios y ejidatarios para participar en proyectos tipo PSA enfocados en la conservación y restauración forestal en donde los participantes podrían recibir compensaciones en efectivo y en especie durante la duración del proyecto. La compensación en especie ofrecida en la encuesta se relacionaba con intervenciones cuyo objetivo era aumentar las condiciones locales en términos de salud, educación, empleo y proyectos productivos (Capitulo 8).

El potencial de desarrollo de proyectos enfocados en los mercados de carbono en el contexto de REDD+ es abordado en el Capitulo 8. Este trabajo propone una opción para la distribución de beneficios de REDD+. Aquí, se propone una separación entre los beneficios e incentivos dirigidos a reducir las emisiones por deforestación y degradación forestal, de aquellos para la valoración de la captura o remoción de carbono en bosques. Bajo este esquema, los proyectos que resulten en la remoción de carbono en bosques podrían ser implementados mas fácilmente por actores privados (p.e. comunidades, empresas, individuos) y ser financiados por medio de mecanismos de mercado similares a los existentes (locales o globales). Por otro lado, los créditos por reducción de emisiones podría ser relativamente mas fácil atribuidos a través de entidades públicas a nivel nacional o sub-nacional; esto serviría para abordar una serie de problemas que pueden surgir dentro de REDD+ como la necesidad de asegurar la integridad en la contabilidad de carbono a nivel nacional para evaluar el desempeño del programa (Capitulo 9).

Los resultados indican que la valoración que los ciudadanos de Guadalajara dan a La Primavera y sus servicios de carbono es suficiente para financiar actividades de mitigación del cambio climático a nivel local. Desde el lado de la oferta de los servicios, el potencial de implementación aumenta si como parte de las negociaciones y mecanismos de compensación se incluyen contribuciones en especie pues esto reduciría las necesidades financieras del programa. Sin embargo, el potencial de implementación también tiene una dimensión geográfica: los resultados indican que habrá mayores tensiones y menor participación en esquemas voluntarios entre las comunidades y propietarios ubicados en las zonas mas cercanas a Guadalajara. Esto se debe a los altos costos de oportunidad en la zona periurbana donde la demanda de terrenos urbanizables provoca un aumento en los precios de la tierra (Capitulo 8). En estas áreas, la conservación de la cubierta forestal y sus beneficios asociados, dependen sobremanera de la capacidad de las diferentes entidades de gobierno para aplicar el marco regulatorio en materia de uso de suelo. Aparte de este efecto focalizado, la prospectiva de implementación es prometedora pues la combinación entre la magnitud de los servicios forestales de carbono que pueden generarse en La Primavera y los precios que podrían ser pagados por los usuarios locales, serian suficientes para superar los costos de provisión y motivar la participación entre los proveedores. El potencial de financiamiento también es mayor que el precio de referencia establecido por el programa nacional de PSA. El potencial para generar acuerdos para la provisión de los servicios forestales de carbono a nivel local también queda de manifiesto en el desarrollo de un proyecto de implementación en el área de estudio, basado en esta investigación (Capítulos 8 y 10).

Los resultados muestran que la inclusión de otros beneficios de las actividades de mitigación del cambio climático, que se disfrutan a nivel local puede aumentar la valoración de los servicios ambientales entre los compradores, incrementando así su disposición al pago. De igual forma, la inclusión de compensaciones en especie que mejoren las condiciones locales de los modos de vida, puede ayudar a reducir la carga financiera de estos programas. Esto también crea la oportunidad para fortalecer el capital social por medio de los procesos de negociación entre los usuarios y proveedores locales. Si todo lo demás se mantiene constante, los mecanismos locales de mercado, aumentarían la disposición a pagar de los compradores y reducirían los costos de provisión, lo que se reflejaría en un mayor nivel de implementación de actividades de mitigación del cambio climático en comparación con un mercado no-local. Además, los mercados locales pueden ofrecer a los actores la oportunidad de reunirse en persona para negociar los acuerdos dentro del mismo contexto cultural, económico e institucional. Esto puede reducir los costos de transacción asociados al monitoreo y verificación de los resultados de implementación, al tiempo que permitiría que los contratos sean formulados dentro de un marco legal común lo que daría mayor certidumbre en cuanto a los pasos a seguir en caso de incumplimiento. La reducción de los costos de transacción de un esquema local, comparado con el mercado global, también incide positivamente en la escala de implementación de las actividades de mitigación del cambio climático. En el caso descrito en este trabajo, entre la Reserva de la Biosfera La Primavera y la ciudad de Guadalajara, la implementación de actividades iniciando a nivel local para después llevarlas a nivel, regional, nacional e incluso global, permitiría la generación de otros beneficios que incrementarían el bienestar social local; la generación de estos beneficios no podría garantizarse si el orden de implementación fuera en el orden contrario.

Con base en los resultados aquí presentados se hacen recomendaciones específicas para el diseño de un marco institucional para un mecanismo de mercado enfocado en los servicios forestales de carbono en México. El marco institucional de un mercado local puede facilitar la implementación de las actividades de mitigación si define cuales son practicas de manejo forestal elegibles así como las áreas donde estas actividades pueden desarrollarse de forma tal que maximicen el valor de los co-beneficios y bienestar de la población local. La negociación entre los proveedores y compradores/usuarios puede facilitarse si los derechos de propiedad sobre los servicios ambientales y la responsabilidad formal por su uso o la generación de emisiones de efecto invernadero, son definidos claramente como parte del marco legal e institucional. Sin embargo, aún si los derechos de propiedad no se han definido completamente dentro del sistema de reglas formales, la generación de la información relacionada con la provisión y uso de los servicios ambientales puede ser suficiente para movilizar a aquellos actores que compartan la misma visión sobre la distribución de los derechos de propiedad sobre los servicios ambientales (i.e. responsabilidad ambiental). La inclusión de mecanismos flexibles de compensación que incluyan una mezcla de incentivos (i.e. compensación en especie), como parte del proceso de negociación de acuerdos, puede servir para involucrar a los proveedores al tiempo que reduce los costos de mitigación y fortalece el capital social. Un problema que frecuentemente surge en la provisión de servicios públicos es el del parasitismo o beneficiarios gratuitos (p.e. Wohar, 1988, en inglés 'free rider'). Sin embargo, como lo muestra el caso de La Primavera, no es necesario que toda la población de Guadalajara participe en el financiamiento de actividades para la provisión de los servicios públicos ambientales. La provisión de los beneficios asociados a la mitigación del cambio climático en La Primavera, así como otros co-beneficios locales, puede obtenerse si menos del 1% de la población de la ciudad participa (Capítulo 7). El potencial de implementación puede aumentar entonces si el marco institucional de estos esquemas promueven la cooperación, solidaridad y subsidiaridad entre los relativamente pocos actores que bastarían para crear el mercado; la participación de estos actores seria suficiente para generar los beneficios para toda la población.

Desde un enfoque más general, desde el punto de vista de la demanda, los resultados indican una preferencia consistente por opciones locales de mitigación del cambio climático considerando que es posible desarrollar estas acciones locales. Las respuestas a los cuestionarios también muestran que si las opciones de mitigación no incluyen acciones locales, los ciudadanos preferirían las opciones más costo-efectivas, como se esperaría dentro de la teoría de mercado (Capitulo 7). Esto indica que cuando los ciudadanos se enfrentan a la selección de opciones de mitigación en el sector forestal pueden seguir un proceso dual de toma de decisión. Por un lado buscarían minimizar el gasto, como se espera por la teoría económica, mientras que en el caso de contar con opciones locales de mitigación estarían dispuestos a maximizar los beneficios y pagar precios mayores. Aunque el efecto de los co-beneficios locales de diferentes medidas de mitigación del cambio climático han sido identificados anteriormente como elementos relevantes para el diseño de políticas públicas (p.e. Pearce, 2000), este aspecto no se había reportado en los estudios de valoración de los servicios forestales de carbono, ni tampoco en la evaluación del efecto que podrían tener en la demanda en mecanismos de mercado; estos dos temas habían sido escasamente investigados. La preferencia social por acciones de mitigación del cambio climático en bosques locales y la producción de co-beneficios refleja un efecto YIMBY ‘Sí-en-mi-patio-trasero`(en ingles, ‘Yes-in-my-back-yard), que puede contribuir al diseño de un marco institucional apropiado que incorpore las medidas de bienestar social local en la valoración de los servicios forestales de carbono.

Samenvatting

Dit werk analyseert, vanuit een multidisciplinair perspectief, de mogelijke rol van marktconforme mechanismen bij het verlenen van koolstofvoorraden uit bosgebieden, aangaande bestrijding van klimaatverandering op basis van de lokale vraag. Deze analyse vergelijkt de mogelijkheden van lokale markten, vanuit het perspectief van een opkomende economie (Mexico), met mondiale marktmechanismen, ontwikkeld onder het Raamverdrag van de Verenigde Naties inzake klimaatverandering (UNFCCC).

Bossen kunnen klimaatverandering helpen te bestrijden met behulp van koolstofdiensten door twee belangrijkste processen in te zetten: in de eerste plaats via vermindering van de CO2-uitstoot als gevolg van ontbossing en bos aantasting en in de tweede plaats via eliminatie van de atmosferische kooldioxide in biomassa en bosbodem door verbetering en/of uitbreiding van bossen.

Marktmechanismen kunnen onderdeel uitmaken van een beloningsbeleid die het voor de verschillende actoren (zowel gebruikers als aanbieders) mogelijk maakt elkaar te ontmoeten en daarbij overeenkomsten aan te gaan om bepaalde goederen en diensten te leveren. In onze hoedanigheid zijn de diensten verbonden aan de mate waarin landeigenaren en gemeenschappen het bosbeheer en milieubeheer vaststellen, waarbij ze een groot aantal voordelen genereren; variërend van het verminderen van klimaatverandering tot aan de instandhouding van biodiversiteit en landschap. De fundamentele motivering van deze strategie is, dat bosbeheerders (dat wil zeggen gemeenschappen of grondeigenaren) vergoeding kunnen krijgen als ze hun bos koolstofdiensten verhogen. Hun prestaties worden gemeten vanuit koolstof voordelen (lagere emissies of van koolstof) die worden verwerkt in de resultaten van feitelijke werkzaamheden en die te vergelijken met een basisscenario. Zodra de voordelen zijn gekwantificeerd, vaak in de vorm van koolstofkredieten, kunnen aanbieders onderhandelen met de vergoedingen van kopers en bijvoorbeeld eisen om hun uitstoot naar elders te compenseren. Echter, dergelijke markten moeten worden gecreëerd. Momenteel zijn er, afhankelijk van hoe de vraag naar koolstof kredieten wordt gecreëerd, twee soorten markten: overeenstemming markten en vrijwillige markten. Daarnaast zijn er andere soorten van beloningsbeleid, zoals Betalingen Voor Milieudiensten (PES), gericht op de uitvoering van bosbescherming in ontwikkelingslanden (hoofdstuk 2). In dit onderzoek is er een studie gemaakt naar de kans op lokale marktmechanismen aan de hand van het model van vrijwillige koolstofmarkten. De schaal van een lokale markt wordt bepaald door het naast elkaar bestaan van potentiële kopers en aanbieders van milieudiensten binnen eenzelfde geografische context (bijvoorbeeld jurisdictie of regio).

Deze studie omvat een analyse van de verschillende elementen van ecologische waarde marktmechanismen binnen een gebied van Mexico als casestudy. De studie richt zich in het bijzonder op het Biosfeer Reservaat van La Primavera in de staat Jalisco in het westen van Mexico en de betrokkenheid van de burgers van Guadalajara, de hoofdstad van Jalisco. De elementen die in dit onderzoek samenkomen zijn de kwantificering en waardering van bos koolstofdiensten, hun potentiële bepaling door landeigenaren en gemeenschappen, de waardering en de financieringsmogelijkheden aansturend op de lokale vraag en de kenmerken van een institutioneel kader die kunnen worden ontworpen en gebruikt als onderdeel van een marktmechanisme.

De belangrijkste methodologische aanpak die is gebruikt, is gebaseerd op milieueconomie en gaat om de waardering van de bos koolstof diensten door lokale gebruikers en leveranciers. Een dergelijke analyse vereist echter aanvullende informatie om de schaal van koolstof diensten te

bepalen, die door de eik en dennenbossen in Mexico kan worden verstrekt. Hiervoor heeft het onderzoek ook bos inventaris technieken opgenomen. De derde benadering die in het onderzoek is opgenomen, is gekoppeld aan het Raamverdrag voor de waardering van koolstof voordelen, ontwikkeld krachtens het internationale programma voor het terugdringen van emissies van ontbossing en bos aantasting van het UNFCCC (REDD +). De mogelijkheden en implicaties van een lokaal marktmechanisme voor bos koolstof diensten worden verkend vanuit twee perspectieven. De eerste benadering is gebaseerd op een standaard vergelijking van de potentiële vraag en de levering van bos koolstof diensten. Indien de waardering door potentiële kopers hoger is dan de bereidheid van landeigenaren en gemeenschappen om hen te voorzien, dan is er ruimte voor onderhandelde overeenkomsten voor de levering van bos koolstof diensten, gecompenseerd door mechanismen op basis van lokale financiering. Meestal streeft de ruilhandel in marktgericht mechanisme naar de waardering van natuurlijke kapitaal en naar het internaliseren van deze waarde in economische transacties. De tweede benadering voor het beoordelen van de mogelijkheid bij lokale markten om bos koolstof diensten te leveren, maakt gebruik van de bestaansmiddelen aanpak van ontwikkeling (Carney, 1998), die de scenario's, waaronder de onderhandelingen plaatsvinden, verbreedt. Deze aanpak maakt het mogelijk om potentiële ruilhandel uit een te zetten, die door in natura compensatie, dan weer lokale duurzame ontwikkeling ondersteund, met als doelstelling lokaal menselijk, productief en sociaal kapitaal (hoofdstukken 2 en 3).

Aan het begin van dit onderzoek werd een participatieve workshop voor aandeelhouders gehouden in Guadalajara, Mexico, om de belangrijkste oorzaken van ontbossing en bosdegradatie in Mexico en daarbij ook de kennislacunes te identificeren. Kennislacunes betreffende de kwantificering, bepaling, de vraag en het institutionele kader van de lokale markten voor bosdiensten. Deze discussies hielpen niet alleen bij het bepalen van specifieke onderzoeksvragen, maar ook bij het bepalen van belemmeringen en kansen voor de uitvoering van de op marktmechanismen in Mexico (hoofdstuk 2). Uit deze analyse werden twee mogelijke soorten gebieden geïdentificeerd waar een dergelijk beleid in Mexico zou kunnen worden geïmplementeerd. De eerste, de beschermde gebieden waar landeigenaren en gemeenschappen meestal niet voor verbod op conventionele economisch productieve activiteiten worden gecompenseerd en die omzetting van bossen voor andere vormen van grondgebruik (bijv. landbouw, grazen, huisvesting) vereisen. De tweede, de droge bossen, waar de voordelen van duurzaam bosbeheer en opbrengst van alternatieve vormen van landgebruik meestal te laag waren voor landeigenaren / gemeenschappen om geïnteresseerd te zijn. Dit omdat de sociale kosten in verband met ontbossing en bosdegradatie hoger zouden zijn dan om deze landen vanuit een economisch perspectief te behouden. Beide voorwaarden waren aanwezig in La Primavera, zodat het mogelijk werd om het potentieel van een lokale markt te bestuderen. In deze context dient de case study inzicht te geven in het gebruik van dergelijke beleidsopties voor het verminderen van klimaatverandering, behoud van biodiversiteit en lokale duurzame ontwikkeling. De kwantificering van bos koolstof diensten, die kunnen worden aangeboden door La Primavera, kan worden vergeleken met de uitstoot van broeikasgassen, geproduceerd in Guadalajara om de bijdrage te beoordelen, die dergelijke acties aan een duurzaam emissie niveau leveren. Door zich te richten op uitvoering van bosbehoud en verbetering van inspanningen in het Biosfeer Reservaat en de onbeschermde wilde dieren passages, die nog steeds La Primavera verbinden met andere beboste gebieden, wordt het mogelijk vast te stellen hoe marktmechanismen bijdragen aan het behoud van biodiversiteit.

Er werden vier ronden van veldwerk en gegevensverzameling uitgevoerd om de hier gepresenteerde resultaten te tonen. Allereerst werd er een inventaris gemaakt van het gemengde eiken-dennenbos La Primavera om het niveau van de koolstofvoorraden in de biomassa van bomen te onderzoeken; deze informatie werd gebruikt om de potentiële levering van bos koolstof diensten in La Primavera in te schatten. De inventaris werd gelaagd naar bedekkinggraad om zo rekening te houden met het effect van bosaantasting (hoofdstukken 4 en 5). Ten tweede werd er, met behulp van keuze experiment methodiek voor ecologische waardering, een enquête onder burgers van Guadalajara uitgevoerd, om zo de waardering van de bos koolstof diensten en het effect van de geografische ligging te bepalen. De enquête stelde aan de deelnemers voor vrijwillige aankoop te overwegen van koolstof emissies tegen wisselende kosten van projecten die waren ontwikkeld in verschillende delen van Mexico. De mogelijkheid om de klimaatsverandering in La Primavera te beperken, werd vertoond samen met twee Biosfeer Reservaten in de staten Durango en Tamaulipas; en er werden drie onderzoeksjaren toepassingsmodi getest om hun invloed op de resultaten te beoordelen (dat wil zeggen twee online en één persoonlijke methode) (hoofdstuk 6). In de derde ronde van het veldwerk werd met burgers uit de lidstaten van Durango en Tamaulipas en met burgers uit Jalisco, maar buiten Guadalajara, dezelfde vragenlijst online gebruikt. In het kader van het experiment werden de geënquêteerden uit deze regio's ook geconfronteerd met de keuze tussen lokale en niet-lokale opties voor koolstof absorberen in bossen. De enquête werd ook gedaan onder de burgers van het grootstedelijk gebied van Mexico Stad, waarvoor er geen lokale omstandigheden was aangeboden (Hoofdstuk 7). Voor de vierde ronde van het veldwerk werd er een keuze experiment onder landeigenaren en gemeenschappen in La Primavera en haar wilde dieren passage ontwikkeld. De enquête onderzocht hun bereidheid om deel te nemen aan PES programma's voor de instandhouding en verbetering van de beboste gebieden. Daarin konden deelnemers contant geld en compensatie in natura ontvangen wanneer ze met het project meededen. Deze voordelen bij deelname in natura, waren gerelateerd aan interventies ter verbetering van lokale omstandigheden met betrekking tot gezondheid, onderwijs, werkgelegenheid en productieve projecten (hoofdstuk 8).

De mogelijke ontwikkeling van projecten die gericht zijn op koolstofmarkten in het kader van REDD + is behandeld in hoofdstuk 9. Dit onderzoek brengt een optie naar voren voor het delen van de voordelen van REDD +. Hier wordt een gedifferentieerde toekenning van de voordelen en de stimulansen voor het verminderen van emissies en voor het verbeteren van de koolstof in bossen voorgesteld. Binnen dit kader kunnen projecten, die resulteren in koolstofverbeteringen in bossen, gemakkelijker en onafhankelijker worden uitgevoerd door particuliere actoren (dat wil zeggen gemeenschappen, bedrijven en particulieren) en worden gefinancierd door de marktmechanismen (lokaal of globaal). Omgekeerd zouden emissiereducties gemakkelijker worden bijgeschreven op publieke actoren op nationaal of subnationaal niveau om een reeks kwesties aan te pakken, zoals de noodzaak van integriteit van koolstof boekhouding en naleving van de nationale prestatiedoelen (hoofdstuk 9).

Resultaten wijzen erop, dat de waardering van de inwoners van Guadalajara ten opzichte van La Primavera en haar koolstof diensten, voldoende is om activiteiten ter vermindering van klimaatverandering lokaal te financieren. Uit een aanbodzijde analyse blijkt dat, wanneer er andere voordelen in opgenomen zijn, de vooruitzichten ter uitvoering ervan verhogen, omdat die de noodzaak voor financiële compensatie verminderen. Echter, de potentiële uitvoering is ook geografisch gerelateerd en de resultaten geven aan dat er, in de gebieden die het dichts bij de stad Guadalajara liggen, spanningen zouden zijn en minder deelname aan vrijwillige regelingen onder gemeenschappen en landeigenaren. Dit komt door de hoge alternatieve kosten in het peri-urbane gebied waar de vraag van huisvesting de grondprijzen verhoogt (hoofdstuk 8). In deze gebieden zal het behoud van het bosareaal en de bijbehorende voordelen sterk afhangen van de capaciteit van overheidsinstellingen om landregelgeving te handhaven en landconversie te voorkomen. Afgezien van dit gedecentraliseerde effect, zijn de vooruitzichten ter uitvoering ervan veelbelovend, omdat de potentiële productie van koolstof diensten en de koolstof prijzen, betaald door lokale gebruikers, voldoende is om tegemoet te komen aan de bereidheid tot acceptatie van leden van gemeenschappen en landeigenaren. De kans op lokale financiering is ook hoger dan de vermelde betaling door het, door de nationale overheid uitgevoerde, PES programma. De mogelijkheid op lokaal niveau voor het genereren van overeenkomsten voor levering van bos koolstof diensten, is ook gebleken uit de ontwikkeling van een eerder project, gebaseerd op dit onderzoek, in het studiegebied (hoofdstukken 8 en 10).

De resultaten tonen aan, dat door toevoeging van een overweging van lokale voordelen, een hogere milieu waardering onder de potentiële kopers in marktmechanismen kan worden geproduceerd, wat de betaalbereidheid verhoogd. Ook kan in natura vergoeding, die de lokale omstandigheden met betrekking tot menselijke en productieve kapitaal tussen aanbieders verbetert, bijdragen tot het verminderen van de financiële vereisten in de op beloning gebaseerde mechanismen. Dit creëert ook een kans tot versterking van het sociaal kapitaal door onderhandelen en door de onderhandelingen tussen lokale gebruikers en producenten van milieudiensten. Als al het andere constant blijft, zullen lokale marktmechanismen door gebruikers taxaties verhoging en kostenvermindering van levering, een hoger niveau van klimaatverandering verminderingmaatregelen implementeren dan bij niet-lokale mogelijkheden. Daarnaast bieden lokale vrijwillige markten de actoren de gelegenheid om elkaar te ontmoeten en afspraken te maken in een gedeeld cultureel, economisch en institutioneel kader. Dit vermindert de transactiekosten in verband met monitoren en verificatie van de resultaten van de uitvoering en zorgt ervoor dat contracten binnen een gedeeld rechtskader hoger zouden zijn, wat meer zekerheid over de te volgen procedure biedt in geval van niet-naleving. De lagere transactiekosten van een lokale regeling, in vergelijking met een wereldwijde markt, heeft ook positieve gevolgen voor de levensvatbare schaal van uitvoering van klimaatwijzigingen verminderingsmaatregelen. In het hier beschreven geval, tussen het Biosfeer Reservaat van La Primavera en de stad Guadalajara, de opbouw van uitvoeringsactiviteiten, van lokaal tot regionaal, vervolgens van nationaal en mondiaal niveau, maakt het genereren van voordelen die de welvaart verhogen mogelijk en die niet wordt gegarandeerd als de mitigatiemaatregelen in de omgekeerde volgorde werden uitgevoerd.

Op basis van de hier gepresenteerde resultaten worden er specifieke aanbevelingen voor een institutioneel kader voor lokale marktmechanismen gegeven. Implementatie kan worden vergemakkelijkt als het lokale marktkader in staat is om een beheerpraktijk te definiëren en de gebieden te bepalen waar activiteiten lokale voordelen en lokaal welzijn kunnen vergroten. De onderhandelingen tussen leveranciers en kopers/gebruikers worden versterkt wanneer de eigendomsrechten over de milieudiensten en de verantwoordelijkheid voor het gebruik ervan, duidelijk als onderdeel van het institutionele kader zijn gedefinieerd. Interessant genoeg, zelfs als eigendomsrechten niet perfect door formele regels zijn gedefinieerd, kan het genereren van informatie over levering en gebruik van milieudiensten nog steeds helpen om actoren te bewegen een gemeenschappelijke visie op milieu eigendomsrechten (dat wil zeggen verantwoordelijkheid voor het milieu) te delen. Het opnemen van flexibele mechanismen waarmee het gebruik van gemengde beloningen (bijvoorbeeld niet-geldelijke vergoeding) als onderdeel van dit onderhandelingsproces, kan helpen de aanbieders te motiveren de kosten van vermindering te verlagen en sociaal kapitaal versterken. Een probleem dat zich vaak bij de verstrekking van openbare goederen voordoet is free riding (bijvoorbeeld Wohar, 1988). Echter, zoals aangegeven bij La Primavera, is het niet noodzakelijk voor de hele bevolking om deel te nemen aan de bepaling van openbare goederen. Het aanbieden van klimaatgerelateerde overheidsuitkeringen en andere lokale voordelen kunnen al worden gerealiseerd als een aantal gelijk aan minder dan 1% van de bevolking van Guadalajara deelneemt. Implementatie vooruitzichten worden verder verbeterd als de regeling de samenwerking, solidariteit en subsidiariteit tussen de relatief weinig actoren bevordert, want het is de deelname van een paar actoren die voor iedereen voordelen genereert.

Een meer algemeen beeld aannemend, geven de resultaten de voorkeur aan een consistente vraagzijde voor lokale project locaties, als deze opties beschikbaar zijn. Uit de reacties van de vragenlijst blijkt ook dat, als de burgers niet een lokale optie worden aangeboden, zij dan liever de meest kostenefficiënte keuze maken, zoals zou worden verwacht van de markt economische theorie (hoofdstuk 7). Dit geeft aan dat, wanneer burgers geconfronteerd worden met bos risicobeperkende opties, zij een dubbele besluitvormingsproces selecteren, waarin zij minimalisering van de uitgaven aanroepen, zoals verwacht van economische theorie, daarbij ook de maximalisatie van de voordelen als lokale actie mogelijk is. Hoewel het effect van lokale voordelen op klimaatverandering verminderingsmaatregelen al eerder is vastgesteld als een relevant element in het algemene ontwerp van het klimaatbeleid (bijvoorbeeld Pearce, 2000), is dit aspect niet opgenomen in de literatuur over de waardering van de bos koolstof diensten of bij de beoordeling van de potentiële vraag in marktmechanismen, beide nauwelijks onderzochte onderwerpen. Deze maatschappelijke voorkeur voor klimaat vermindering in lokale bossen en de productie van voordelen,weerspiegelt een 'ja in mijn achtertuin' effect dat kan helpen bij het ontwerpen van passende institutionele kaders, die lokaal welzijn in de waardering van de bos koolstof diensten er in opnemen.

Author Biography

Since a young age Arturo has been interested in the environment. He holds a Bachelor of Environmental Engineering from ITESO University in Mexico. He subsequently worked for almost five years in environmental consultancy projects and in the coordination of environmental actions in the industrial sector in Mexico. Back then he got interested into the study of forestry-based actions for climate change mitigation, rural development and biodiversity conservation. Then he enrolled in the MSc program in Environmental Economics and Environmental Management (EEEM) at The University of York, England. In 2007 he obtained the MSc degree (distinction) and was co-awarded the Prize of the Environment Department for the EEEM program that year. His master dissertation focused on the study of carbon sequestration costs in marginal rural areas including an econometric analysis of landowners' decision making when joining reforestation projects in voluntary carbon markets (Scolel Té project); he carried out field work in Chiapas Mexico. His main interest was to understand how these projects could be developed at lower costs and be attractive to landowners and communities to promote participation. Arturo returned to Mexico and lectured at the Environmental Engineering program of ITESO University in 2008. He joined the UT in September 2008 to pursue a Ph.D. degree and continue his research on Valuation of Environmental Services and Rural Development. After considering the difficulties to generate meaningful levels of demand for forestry-based projects in the global carbon markets, he decides to study the valuation of forest carbon services from the demand side and the potential for local markets. His research is focused on the analysis of the factors that could drive the supply and demand of environmental services on a carbon basis of dry forests in Mexico. The Ph.D. research was supervised by Prof. Dr. Jon Lovett and Dr. Margaret Skutsch. He got scholarships from CONACYT and SEP from the Mexican government; research costs were covered by grants from DEFRA's Darwin Initiative and NWO WOTRO. As part of his Ph.D. research he had the opportunity to collaborate in the design of an implementation project in the study area; the research project was featured by the Darwin Initiative as project of the month in July 2012. Research findings have been presented and published in different journals, symposiums, media and conferences targeting different audiences. He is interested in continue working in the design of environmental policy instruments for ecosystem management and climate change mitigation and to investigating the potential contribution of these interventions to local sustainable development and biodiversity conservation in a low carbon economy.